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# Impact of Moisture on Baled Cotton

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**Abstract.** *The purpose of this research was to determine if moisture applied before packaging caused fiber degradation during subsequent storage. Fiber quality characteristics of universal density cotton bales were determined before and after extended storage (months) in three separate studies. For the test bales, water was sprayed over the top of the fiber as it came down the lint slide after ginning and cleaning. The bales were then packaged at universal density and placed in either tripled polyethylene bags, woven polypropylene bags, or fully coated woven polypropylene bags, and then stored at atmospheric conditions. Initial moisture content after the water was added ranged from less than 5% to over 15%. The bales changed weight and moisture substantially during storage depending on the type of bale covering and the initial moisture content. Most fiber quality characteristics except color remained about the same. The HVI color decreased from Middling (31) before storage to as low as Strict Low Middling Spotted (43) after storage depending on moisture content. Other HVI data changed slightly during storage regardless of the moisture level. The higher initial moisture contents resulted in greater degradation in color. Cotton bales should not be stored at moisture contents above 7.5%, wet basis, regardless of bale covering materials.*

**Keywords.** Cotton, Moisture, Color, Degradation, Water, Density, Bales

## Introduction

Cotton fiber seeks to reach equilibrium with the moisture in the air. When the cotton fiber is not compressed, it gives up moisture readily at low humidity but absorbs moisture much more slowly at high humidity unless wetting agents are used. Cotton may be harvested, ginned and initially stored at moistures below equilibrium moisture content, especially if the storage area is humid. The cotton bales seek equilibrium with the moisture in the air and usually gain but sometimes lose weight during storage. Farmers are paid on the certified weight at the gin or warehouse so ginners often restore moisture at the lint slide to recover the weight lost during field drying and gin processing, and to reduce bale-packaging forces (Anthony, Van Doorn and Herber, 1994). Two basic methods are used—humidified air and direct water spray. The humidified air approach rarely adds more than 2% moisture to a bale but the direct spray approach can add far more moisture. Thus, the direct spray approach must be used with great care because of potential fiber quality degradation.

Griffin and Harrell (1957) investigated the effect of adding moisture at the lint slide on lint quality and bale weight for 18 bales packaged at 192 kg/m$^3$ (12 lb/ft$^3$), covered with jute bagging and stored for 70 days. They considered different amounts of moisture sprayed on the fiber with and without a surfactant with nine nozzles as the lint came down the lint slide. The amounts ranged from 0 to 37.2 kg (82 lb) per bale in 1953-54. They conducted a similar study with six bales in 1954-55 except that the bales were packaged at standard density (about 320 kg/m$^3$ or 20 lb/ft$^3$) and 0 to 16.2 kg (35.7 lb) of water was added per bale. In 1953-54, bale moistures ranged from 3.9% to 18.8% whereas they ranged from 4.6% to 9.0% in 1954-55. They found that all the bales either gained or lost weight as they tried to reach equilibrium with the atmosphere at about 7% moisture content. Of the 18 bales in their 1953-54 study, severe damage attributed to the addition of moisture at the lint slide occurred for the bales packaged at over 15% moisture; these bales developed mildew and fungal growth and were too damaged to officially class. No damage to fiber quality or spinning properties was evident in bales packaged below 9% moisture. For the 1954-55 study, the color grade was reduced from Strict Low Middling to Low Middling when moisture was added at the lint slide to raise the moisture content even at storage moistures of 6.2%—this happened regardless of the amount added. They also reported that the center of the bales had not equilibrated with the atmosphere after 91 days. Anthony (1982) found similar results with equilibration from 100 samples taken throughout bales stored for several months.

After the cotton fiber is packaged into a bale, moisture transfer occurs very slowly especially at high densities. In fact, bales at densities of 192 kg/m$^3$ (12 lb/ft$^3$) required over 60 days to equilibrate with the environment while bales at 448 kg/m$^3$ (28 lb/ft$^3$) required over 110 days (Anthony, 1982). Equilibration time is also a function of the starting moisture as well as the humidity and temperature of the environment. The bales attempt to reach equilibrium with the environment and the rate of adsorption and desorption is influenced by bale density, ambient temperature and humidity, bale covering, surface area, air changes, fiber history, etc. (Anthony, 1997). Anthony (1982) stored low-moisture bales for periods up to one year and found that moisture gain was a function of density, climatic conditions and bale covering. He considered jute, burlap, woven polypropylene, strip-laminated woven polypropylene, dimpled polyethylene and polyethylene. Bales covered in the relatively impermeable polyethylene required much more time (over 365 days) to equilibrate with the environment than the other bale coverings (over 120 days).

Bale covering materials in widespread use during 1991, included burlap, woven polypropylene with laminated strips of polyethylene to prevent fibrillation, and polyethylene with 0.95 cm (3/8-inch) diameter perforations on 45.7 cm (18-inch) centers to allow air to escape during bag emplacement and moisture transfer. Anthony and Herber (1991) studied the moisture transfer characteristics of these materials applied over universal density bales that were packaged at 3.5% moisture and stored at 21.1 °C (70 ºF) and 80% relative humidity. They reported that the woven polypropylene-covered bales reached equilibrium in less than 161 days whereas the polyethylene-covered bales had not reached equilibrium after 378 days. After 161 days, the polyethylene-covered bales had gained only about 40% as much moisture as the polypropylene-covered bales. With the exception of the Griffin and Harrell report, published information addresses moisture entering rather than leaving the bale. Barker and Laird (1993) reported that desorption occurs at about twice the rate of adsorption for small samples of lint. Thus, bales should lose moisture much faster than they gain moisture. New bale covering materials are also being considered to improve the bale package and to reduce costs. In 2002, U.S. bales were packaged mostly in woven polypropylene (strip-coated or fully coated) (53%), polyethylene (39%), and burlap (8%) (Thompson, 2003). The moisture transfer characteristics of the fully coated woven polypropylene bagging has not been fully evaluated.

The addition of moisture to cotton fiber immediately before baling reduces compression forces, increases bale weight and reduces equilibration time. Generally, less than two percentage points of moisture (4.54 kg or 10 lb) can be added to a bale of cotton by the humidified air approach. The direct-spray method can add a much greater amount of water but is generally limited to keep final bale moisture to less than 8%. Based on the work of Griffin and Harrell (1957), bales should not be covered with jute bagging and stored above 9% moisture content. Note that bales are currently (2002) packaged at higher density levels and covered with much less permeable bagging; both retarding the escape of moisture from the bale. Later research by Anthony (2002a, 2002b and 2003) suggests that even lower levels of moisture should be used. Recent complaints from the textile industry suggest that fiber color sometimes changes substantially during storage prompting some to suspect excess moisture as the causative (Brandon, 2003). The change in color during storage can be devastating to the cotton industry.

Since cotton fiber gains moisture more rapidly before it is compressed, moisture restoration before packaging hastens equilibration of the baled fiber with the moisture in the air. Previous research established initial limits for the moisture allowable in baled lint; however, sensors to accurately measure moistened fiber at the gin are not readily available. In fact, rapid measurement of the moisture in cotton bales is very difficult, and becomes even more complex when water is sprayed directly to the cotton at the lint slide. Anthony (2001) reported success with hydraulic methods of moisture measurement whereas Byler, et al. (2001) reported acceptable levels of accuracy using patented resistance-based sensors developed by Byler and Anthony (1996). Until suitable methods to measure the moisture of baled cotton are readily available, care must be exercised to ensure that excessive moisture is not added to bales.

## Purpose

The purpose of this research was to determine if moisture sprayed on cotton at the lint slide could adversely impact the quality of fiber stored in bales covered in 1) relatively impermeable bagging, 2) conventional strip-coated woven polypropylene bagging, and 3) fully coated, woven polypropylene bags.

## Methodology

Three studies were conducted over a two-year period. The methodology common to all studies and the methodology specific to each study are explained separately.

### *Common Methodology*

About 635.6 kg (1400 lb) of seed cotton was ginned to produce each 227 kg (500 lb) bale for each treatment. Each bale was placed in a six-mil thick polyethylene bag until the ginning phase was completed, then the bales were stored in the appropriate bagging. The ginning phase of each of the three studies was completed in one day. The cotton was processed through a dryer, cylinder cleaner, stick machine, dryer, cylinder cleaner, extractor feeder/gin stand, and one saw-type lint cleaner in the full-scale gin at the Stoneville Ginning Lab. As the lint came down the lint slide in thin batts (2.5 to 5.1 cm or 1 to 2-inches thick), three conventional spray nozzles applied plain water to the surface of the cotton (Figure 1). Spray nozzles were equipped with 0.051, 0.075, 0.025, or 0.025 mm (0.002, 0.003, 0.001 and 0.001-inch) diameter tips, depending on the test design. The three nozzles were connected to a standard residential water line equipped with flow and pressure regulators for water supply. The output of the tips at various valve settings was calibrated by capturing the water from the nozzles for a period of time.

Samples were taken as the cotton came up the lint flue to the battery condenser for High Volume Instrument (HVI) evaluation (5 each), moisture determination by the oven method (ASTM, 1971) (10 each), and Advanced Fiber Information System (AFIS) (5 each) analyses. After moisture was added, 10 samples were taken for lint moisture evaluation. The bales were pressed to a platen separation of about 48.3 cm (19-inches) and restrained with 9-gauge, 226.1 cm (89-inch) long wire ties, and temporarily placed in polyethylene bags. After the ginning phase was completed, the bales were placed in the appropriate bags for storage at ambient conditions for the required storage period. The bales were then stored in a gin building and subjected to conditions inside the building, which were generally 15.6 to 26.7 °C (60 to 80°F) with humidity fluctuating proportionate to climatic conditions outside. The bales were weighed tow or three times per week during the storage period. Temperature and relative humidity were not recorded.

After the storage period, the bales were sampled at 10 intermediate locations (layers) about 6.4 cm (2.5-inches) apart as shown in Figure 2. The cotton was separated at each layer and samples taken (Figure 3). Sub-samples were taken at each layer for moisture content (9 or 10 each) determination by the oven method (ASTM, 1971), Advanced Fiber Information System (AFIS) (10 each), and HVI classification (9 or 10 each). The "before and after storage" samples for classification and the AFIS samples were each processed at the same time in order to remove instrument bias. The HVI classification analysis was conducted by the Agricultural Marketing Service at Dumas, AR. Lint moisture and AFIS evaluations were conducted at the Stoneville Ginning Laboratory. The HVI and AFIS samples were conditioned to meet ASTM requirements before the samples were tested.

### *Study 1*

Five bales of Stoneville 4892BR variety cotton harvested October 11, 2000, were ginned May 25, 2001. For treatment number 1, no moisture over spray was used. Two additional layers of six-mil thick polyethylene bags were placed over the initial bag for bale storage. The triple-sealed polyethylene covering was used to maintain the moisture in the bale as consistent as possible. This covering method is not used commercially; however, the study was conducted to establish the response of fiber properties to a specific moisture level and the tripled bags greatly reduce moisture transfer. The bales were then weighed and placed in storage (Figure 4) at ambient conditions for a period of 116 days. The bales were taken out of storage on September 18, 2001.

### *Study 2*

Six bales of Stoneville 747 variety cotton were ginned November 16, 2001. Water quantities were about 18.1, 10.9, 22.7, 7.3, 0, 5.4 kg (40, 24, 50, 16, 0 and 12 lb), respectively, for treatments 1-6. The bales were placed in industry-approved, strip-laminated, woven polypropylene bags and then weighed. The bales were then stored (Figure 5) for a period of 149 days. As shown in Figure 5, the tops of the bags were not folded and fastened as is normal practice but were left open. The bales were taken out of storage on April 16, 2002.

### *Study 3*

Twelve bales of Suregrow 501 variety cotton were ginned May 29, 2002. Water quantities of about 13.6, 11.3, 15.9, and 9.1 kg (30, 25, 35, and 20 lb), respectively, for treatments 1-4 were desired. Eleven of the bales were then weighed and placed in bagging that is just coming into use in the industry--fully coated woven polypropylene bags. These bags had 20 each 3.81 cm (1½-inch) moon shaped vent holes. For a control, one (bale 12) was placed in a strip-coated, woven polypropylene bag. All bales were stored (Figure 6) for a period of 188 days. The bales were taken out of storage on December 3, 2002.

## Results

### *Study 1*

Based on calculations from the moisture levels before and after moisture addition as determined by the oven method, 0, 5.4, 9.1, 19.1, and 21.8 kg (0, 12, 20, 42 and 48 lb) were added per bale (Table 1). The initial bale weights ranged from 231.3 to 258.6 kg (510 to 570 lb), respectively. Lint moisture contents in the lint flue prior to moisture being added were 6.0, 5.8, 5.1, 5.5 and 5.2%, respectively, for moisture levels 1-5. The moisture contents after the over spray were 6.0, 7.3, 8.9, 13.9 and 15.4 %, respectively, for moisture levels 1-5. The temperature and humidity during storage averaged 26 ºC (80 ºF) and 82%, respectively. After storage, the final moisture contents were 6.1, 7.9, 8.2, 11.6 and 12.9%. When the polyethylene coverings were removed from the bales, visible water damage in the form of yellow or dark discolorations as shown in Figure 7 was typical in all bales where moisture was added. Table 2 contains final moisture contents in the bales after storage for each of the layers of cotton within each bale and shows the standard deviation of the final moisture increased substantially as initial moisture levels increased. The standard deviation for final moisture was 0.12 when no moisture was added and 0.99 when 21.8 kg (48.0 lb) of water was added, clearly indicating that the bale had not reached equilibrium. The distribution of moisture within the bale after storage is illustrated in Figures 8 and 9 for the low and high moisture bales, respectively. The moisture of the bale without any over spray remained relatively constant during storage at 6% versus 6.1% moisture content. The bale with limited amount of water added (5.4 kg or 12 lb) changed its moisture content from 7.3 to 7.9%. The bale that had 9.1 kg (20 lb) of water added changed its moisture content from 8.9 to 8.2%. The two bales with the high levels of moisture also lost moisture during storage.

The AFIS data before and after bale storage (Table 3) suggests that fiber length and neps decreased during storage while short fiber content increased regardless of whether moisture was added or not. Compared to the control, moisture did not appear to substantially affect the AFIS data. Sample classification before and after the storage period by the Agricultural Marketing Service is presented in Table 4. The HVI color decreased from Middling (31) to Strict Low Middling Spotted (43) as moisture content at the beginning of storage increased from 6.0% to 15.4% (Figure 10). Reflectance or Rd averaged 75.7, 74.7, 73.6, 70.6, and 69.3, while Yellowness (plus b) averaged 8.5, 8.9, 9.3, 10.1, and 10.6, respectively, for moisture levels 1, 2, 3, 4, and 5. The decrease in Rd by 6.7 units and the increase in Plus b of 2.1 units were the most important impact of moisture was also critical. Thus, the bales became darker and more yellow as lint moisture increased; even 5.4 kg (12.0 lb) of water added per bale increased yellowness and grayness substantially during storage. Fiber length uniformity appeared to increase during storage, regardless of the fiber moisture content.

***Study 2***

As shown in Figure 5, the tops of the bags were not folded and fastened as is normal practice but were left open; this procedure may have hastened moisture transfer. Based on calculations from the moisture levels as determined by the oven, 18.3, 12.8, 17.1, 8.5, 0, and 5.6 kg (40.4, 28.2, 37.7, 18.8, 0, and 12.4 lb) of water were added to bales 1-6, respectively (Table 5). Lint moisture contents in the lint flue prior to moisture being added were 4.9, 4.7, 4.7, 4.7, 4.9, and 4.8%, respectively, for bales 1-6. The moisture contents after the over spray was applied were 12.7, 10.4, 12.0, 8.5, 4.8 and 7.4 %, respectively for bales 1-6. The temperature and humidity during storage averaged 11ºC (51ºF) and 81%, respectively. After the bale storage was completed (149 days), the final moisture contents were 8.2, 7.0, 7.6, 6.4, 6.1, and 6.6%. The distribution of moisture at each layer is illustrated in Figures 11 and 12 for the low and high moisture bales, respectively. As can be seen in Figure 12, the bale had not reached equilibrium with the air. No visible water damage was observed except near the bale ties for the higher moisture bales (Figure 13). The weight change for each moisture level is shown in Figure 14. The 4.8% moisture bale gained weight but all the others lost weight. Moisture change is estimated for each bale in Figure 15. The bale without any over spray increased from 4.8 to 6.1% moisture content during storage. The bale with limited amount of water added changed its moisture content from 7.4 to 6.6%. The bale with 8.5 kg (18.8 lb) of water added, changed its moisture content from 8.5 to 6.6%.

The AFIS data for the cotton before and after storage is in Table 6. Generally, the “after” storage AFIS data differed from the pre-storage data; however, when compared to the “control” bale (4.8 % moisture), no clear differences were present except for length at the 12.7% moisture level.

Sample classification by the Agricultural Marketing Service for the bales before and after storage is presented in Table 7. The mode HVI color before storage was 31, 31, 31, 31, 32, and 31 for bales 1, 2, 3, 4, 5 and 6, respectively. The bales should have all been the same color before storage; however, 5 of the 9 samples for bale 5 were color 32 and four were color 31, so the mode color was called 32. Rd averaged 74.7, 74.2, 74.6, 74.3, 73.3 and 73.6, while Plus b averaged 9.2, 9.0, 8.9, 9.0, 9.2 and 9.1, respectively, for bales 1, 2, 3, 4, 5 and 6. After storage, the bales initially above 8.5% moisture were graded Middling Light Spot (32) as compared to 31 before storage (Figure 16). After storage, color levels were 32, 32, 32, 31, 32 and 31, for bales 1, 2, 3, 4, 5 and 6, respectively. Reflectance values were 73.5, 73.4, 73.1, 74.1, 74.0, and 74.3 for bales 1, 2, 3, 4, 5 and 6, respectively (Figure 17). Reflectance increased slightly for bales stored initially at 7.4 and 4.8% moisture but decreased for bales at 8.5% moisture and above. Yellowness was 9.5, 9.4, 9.6, 9.1, 9.3, and 9.2 for bales 1, 2, 3, 4, 5 and 6, respectively. The change in reflectance and Plus b is shown in Figure 18.

Bales with initial moisture levels of 12.7, 12.0 and 10.4% dropped from color 31 to color 32 during storage; however, the bale at 8.5% initial moisture did not drop in color as previous studies suggested. Unfortunately, the Rd and Plus b values for all the bales were near the line separating white from light spot as well as the line separating Middling from Strict Low Middling and created difficulties in interpreting the color data. The HVI length data did not support the negative effect of 12.7% moisture on fiber length as reported for the AFIS data.

### *Study 3*

Data collected during ginning and the weight change during storage is at Table 8. The initial bale weights ranged from 202 to 226 kg (446 to 496 lb). Based on calculations from the moisture levels as determined by the oven after storage and the initial bale weight, 9.57, 9.62, 12.79, and 6.4 kg (21.1, 21.2, 28.2 and 14.1 lb) of water were added, respectively, at each level. The control bale (1047) weighed 220.2 kg (484 lb) and had 6.6 kg (14.5 lb) of water added which was about the same as the lower level for the fully coated bales. Lint moisture contents in the lint flue prior to moisture being added ranged from 4.8 to 5.3% (Table 9). The moisture contents after the over spray was applied averaged 10.7, 9.6, 9.0, and 8.1% for the four levels of moisture, and 7.8% for the control bale. The temperature and humidity during storage averaged 12ºC (72ºF) and 83%, respectively. After the bale storage was completed (188 days), the final moisture contents were 8.7, 8.2, 7.9, and 7.3%, for levels 1, 2, 3 and 4. Final moisture was 6.6% for the control bale indicating that the strip-coated bale lost more moisture than the fully coated bales.

The bales with about 12.7 kg (28 lb) of water added, changed their moisture content from 10.7 to 8.7% (Table 8) and lost about 4.1 kg (9 lb) of weight. The bales at about 9.6% and 9.0% initial moisture also lost moisture and weight during storage. The two fully coated bales with about 6.4 kg (14 lb) of water added changed from 8.1% to 7.3% and lost about 1.4 kg (3 lb) of weight; however, the bale in the strip-coated, woven polypropylene bag changed its moisture content from 7.8 to 6.6% and lost about 1.8 kg (4 lb) of weight. Thus, all bales lost weight during storage. The distribution of moisture at each layer is illustrated in Figures 19 and 20, and indicates that the moisture variation across the different layers of the bale was generally about 0.5% suggesting that the moisture within the bale had not equilibrated within the bale. Further evidence that the bales had not reached equilibrium with the environment is provided by the fact that the final moistures in the bales ranged from 6.6% to 8.7%. The periodic weight change and the calculated moisture change are at Figures 21 and 22, respectively, and illustrate the continuous decline in moisture and weight.

Sample classification data for the bales before and after storage is presented in Table 10 for each bale. The mode HVI color was 31 for all bales before storage except 2 and 7, which were 21. After storage, all bales graded 32 except bale 9 that graded color 43—bale 9 was one of the three bales that had 12.7 kg (28 lb) of water added. Statistical analyses of the change in HVI properties during storage with the SAS General Linear Models procedures (Table 11) indicated that all properties were changed significantly (SAS, 2001). The mean HVI data for each moisture level is at Table 12. The significant change in micronaire, strength, Rd, and Plus b, followed a fairly consistent pattern of increasing with moisture; however, the other variables did not suggesting that moisture did not impact leaf, % area, length and uniformity. The HVI-factor response to the bales at the 10.7% moisture level seemed to differ from most other levels. Reflectance values generally changed from 1 to 6 units during storage whereas Plus b changed from 0.4 to 1.6 units, both in the direction of lower grade. Fiber length, uniformity and strength appeared to improve with storage whereas leaf and micronaire appeared to respond negatively. The HVI data is given in Table 13 for each layer of each bale and indicates the typical variations within the bale. The change in reflectance and Plus b is shown in Figure 23.

Even though the control bale lost more moisture than the two bales with about the same amount of water added, its fiber quality responded in the same manner. Thus, the initial moisture of 7.8% in the more permeable strip-coated bagging was just as damaging as the 8% moisture in the fully coated bagging suggesting that the safe storage moisture is actually less than 7.8%. Obviously this applies to the direct-spray and may or may not apply to the humidified air method since it was not considered in these studies.

The AFIS data for the cotton before and after storage is in Tables 14 and indicates that no substantial differences occurred due to storage under elevated moisture conditions. Statistical analyses with the SAS General Linear Models procedure (not shown), indicated moisture was not significant for the change in any AFIS data (SAS, 2001).

## Summary

The purpose of these studies was to determine if degradation in fiber quality occurred during storage of cotton bales at elevated moisture contents. In Study 1, five bales of cotton were ginned and varying amounts of moisture was sprayed on the cotton as it came down the lint slide. For these bales, approximately 0, 5.9, 9.1, 21.8, 25.0 kg (0, 13, 20, 48 and 55 lb) of water was used. Initial moisture contents after the water was added and before storage ranged from 6% for the bale with no over spray to 15.4% for the highest amount of water added. After 116 days of storage, the bale in which no over spray had been applied remained at about 6% moisture content. All other bale moistures had changed somewhat even though the bales were triple sealed in polyethylene bags. AFIS measurements indicated that fiber length and neps decreased during storage while short fiber content increased regardless of moisture. The HVI color decreased from Middling (31) to Strict Low Middling Spotted (43) as moisture content increased from 6.0% to 15.4%. Reflectance (Rd) and Yellowness (+b) values indicated the bales became darker and more yellow as moisture increased.

In Study 2, the impact of spraying moisture on cotton fiber at the lint slide, packaging the bales at universal density, and storing the bales for 149 days at atmospheric conditions was evaluated. From 0 to 18.1 kg (40 lb) of water was sprayed on cotton fiber of six bales at the lint slide before packaging and placing in strip-coated, woven polypropylene bags and storing the bales. Initial lint moistures prior to moisture addition were about 4.8%. Moisture contents after the over spray was applied ranged from 4.8 to 12.7%. After the bale storage phase was completed, the final moisture contents ranged from 6.1 to 8.2%. The bale without any over spray increased from 4.8 to 6.1% moisture content during storage and the bale with 18.1 kg (40 lb) of water added changed its moisture content from 12.7 to 8.2%. All bales that had moisture added lost weight during storage. The initial HVI color was 31 for all bales except the control bale that was color 32. After storage, the bales initially above 8.5% moisture were graded Middling Light Spot (32) as compared to Middling (31) before storage. Reflectance decreased 6.7 units while Plus b increased 2.1 units due to storage at high (12.7%) moisture.

In Study 3, from 6.3 to 13.1 kg (13.9 to 28.9 lb) of water was sprayed on the fiber for 12 bales of cotton as the fiber came down the lint slide. Moisture contents before moisture addition ranged from 4.8 to 5.3% and from 7.8 to 10.8% after moisture addition. After packaging 11 of the bales at universal density and storing for 188 days in fully coated woven polypropylene bags, moisture contents ranged from 6.6 to 8.9%. Note that a control or reference bale was packaged at 7.8% moisture in a strip-coated woven polypropylene bag. The color grade of bales at all moisture levels changed from Middling (31) or better to Middling Light Spot (32). Fiber properties measured by the AFIS were not significantly impacted by moisture. However, all HVI properties were significantly influenced by moisture and storage. Only color and its two components, Rd and Plus b, as well as micronaire and strength changed substantially due to moisture.

## Conclusions

Care must be exercised in spraying water on cotton fiber at the lint slide to avoid fiber damage. The color of cotton degrades during storage at universal density when water is added to bring moisture levels above 7.5% (wet basis), regardless of bale covering materials. The more impermeable the bale covering, the less water can be added.

## Disclaimer

Mention of a trade name, proprietary product, or specific machinery does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

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Table 1. Initial ginning data and final moisture content for Study 1.

| Moisture level | Bale | Water added, kg* | Bale weight, kg | Pressure, kPa | Bale moisture, % | | |
|---|---|---|---|---|---|---|---|
| | | | Initial | | Lint flue | Initial | After 116 days |
| 1 | 1 | 0.0 | 242.4 | 16,822 | 6.0 | 6.0 | 6.1 |
| 2 | 5 | 5.4 | 231.5 | 11,558 | 4.8 | 7.3 | 7.9 |
| 3 | 4 | 9.1 | 233.4 | 11,482 | 5.1 | 8.9 | 8.2 |
| 4 | 2 | 19.1 | 258.8 | 12,537 | 5.5 | 13.9 | 11.6 |
| 5 | 3 | 21.8 | 246.1 | 9,212 | 5.2 | 15.4 | 12.9 |

*Calculated from difference in lint moisture.

Table 2. Final moisture content in the bale after 116 days of storage for Study 1.

| Initial moisture level, % | Final moisture, % | | | | |
|---|---|---|---|---|---|
| | Layer | Mean | Standard deviation | Minimum | Maximum |
| 6.0 | 0 | 6.06 | 0.116 | 5.90 | 6.30 |
| | 1 | 6.30 | 0.123 | 6.10 | 6.50 |
| | 2 | 6.18 | 0.173 | 5.95 | 6.40 |
| | 3 | 6.03 | 0.129 | 5.85 | 6.20 |
| | 4 | 6.14 | 0.119 | 6.00 | 6.40 |
| | 5 | 6.04 | 0.104 | 5.90 | 6.25 |
| | 6 | 5.91 | 0.134 | 5.70 | 6.05 |
| | 7 | 6.04 | 0.080 | 5.85 | 6.15 |
| | 8 | 6.00 | 0.121 | 5.80 | 6.20 |
| | 9 | 5.90 | 0.084 | 5.80 | 6.05 |
| 7.3 | 0 | 7.96 | 0.395 | 7.65 | 8.85 |
| | 1 | 7.76 | 0.180 | 7.50 | 8.00 |
| | 2 | 7.86 | 0.189 | 7.65 | 8.20 |
| | 3 | 8.01 | 0.163 | 7.75 | 8.25 |
| | 4 | 7.86 | 0.328 | 7.55 | 8.55 |
| | 5 | 7.95 | 0.327 | 7.60 | 8.65 |
| | 6 | 8.05 | 0.219 | 7.75 | 8.45 |
| | 7 | 7.98 | 0.123 | 7.85 | 8.15 |
| | 8 | 7.72 | 0.204 | 7.40 | 8.00 |
| | 9 | 8.08 | 0.324 | 7.55 | 8.60 |
| 8.9 | 0 | 8.34 | 0.306 | 7.95 | 8.80 |
| | 1 | 8.24 | 0.165 | 8.00 | 8.60 |
| | 2 | 8.18 | 0.233 | 7.90 | 8.75 |
| | 3 | 8.07 | 0.221 | 7.80 | 8.50 |
| | 4 | 8.20 | 0.248 | 7.90 | 8.75 |
| | 5 | 8.31 | 0.313 | 7.90 | 8.80 |
| | 6 | 8.00 | 0.148 | 7.85 | 8.35 |
| | 7 | 8.24 | 0.253 | 7.95 | 8.80 |
| | 8 | 8.35 | 0.319 | 8.00 | 8.75 |
| | 9 | 8.17 | 0.345 | 7.90 | 9.10 |
| 13.9 | 0 | 12.37 | 1.072 | 11.05 | 13.85 |
| | 1 | 11.64 | 0.346 | 11.10 | 12.30 |
| | 2 | 12.26 | 1.189 | 10.95 | 14.20 |
| | 3 | 11.70 | 0.923 | 10.90 | 13.70 |
| | 4 | 11.21 | 0.443 | 10.70 | 11.85 |
| | 5 | 11.06 | 0.461 | 10.45 | 11.85 |
| | 6 | 11.28 | 0.383 | 10.75 | 11.95 |
| | 7 | 10.88 | 0.332 | 10.60 | 11.60 |
| | 8 | 11.18 | 0.480 | 10.75 | 12.20 |
| | 9 | 12.36 | 0.992 | 11.10 | 13.45 |
| 15.4 | 0 | 13.11 | 0.848 | 12.35 | 14.85 |
| | 1 | 13.51 | 1.613 | 11.60 | 15.55 |
| | 2 | 12.04 | 0.614 | 11.35 | 13.40 |
| | 3 | 11.70 | 0.427 | 11.05 | 12.60 |
| | 4 | 12.62 | 1.051 | 11.45 | 14.35 |
| | 5 | 14.24 | 1.347 | 11.70 | 16.20 |
| | 6 | 12.63 | 0.805 | 11.80 | 14.20 |
| | 7 | 13.15 | 1.333 | 11.80 | 15.10 |
| | 8 | 12.97 | 0.896 | 12.10 | 14.40 |
| | 9 | 13.22 | 1.011 | 12.35 | 15.30 |

Table 3. Advanced Fiber Information System (AFIS) data (see Appendix A for acronyms) and moisture before and after storage for Study 1.*

| | Moisture content, % | L(w), cm | UQL (w), cm | SFC (w),% | IFC, % | Mat ratio | Neps per gm | SCN per gm | Dust, gm | Trash, gm | VFM, % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Before | 6.0 | 2.47 | 2.95 | 7.59 | 3.46 | 0.893 | 207 | 11.0 | 503 | 111 | 1.95 |
| After | 6.1 | 2.44 | 2.93 | 8.52 | 3.65 | 0.895 | 189 | 11.8 | 504 | 109 | 1.99 |
| **Change** | **0.1** | **-0.03** | **-0.02** | **0.93** | **0.19** | **0.002** | **-18** | **0.8** | **1** | **-2** | **0.04** |
| Before | 7.3 | 2.45 | 2.93 | 8.15 | 3.50 | 0.887 | 215 | 11.0 | 390 | 91 | 1.64 |
| After | 7.9 | 2.41 | 2.91 | 9.04 | 3.68 | 0.887 | 204 | 10.1 | 389 | 91 | 1.64 |
| **Change** | **0.6** | **-0.04** | **-0.02** | **0.89** | **0.18** | **0.000** | **-11** | **-0.9** | **-1** | **0** | **0.00** |
| Before | 8.9 | 2.43 | 2.91 | 8.16 | 3.54 | 0.888 | 217 | 10.8 | 412 | 95 | 1.72 |
| After | 8.2 | 2.40 | 2.89 | 8.75 | 3.56 | 0.889 | 202 | 10.1 | 390 | 96 | 1.70 |
| **Change** | **-0.7** | **-0.03** | **-0.02** | **0.59** | **0.02** | **0.001** | **-15** | **-0.7** | **-22** | **1** | **-0.02** |
| Before | 13.9 | 2.42 | 2.91 | 8.46 | 3.58 | 0.887 | 227 | 11.0 | 417 | 98 | 1.76 |
| After | 11.6 | 2.40 | 2.90 | 9.09 | 3.47 | 0.896 | 209 | 10.6 | 419 | 104 | 1.90 |
| **Change** | **2.3** | **-0.02** | **-0.01** | **0.63** | **-0.11** | **0.009** | **-18** | **-0.4** | **2** | **6** | **0.14** |
| Before | 15.4 | 2.41 | 2.90 | 8.69 | 3.39 | 0.889 | 228 | 10.4 | 455 | 99 | 1.76 |
| After | 12.9 | 2.39 | 2.89 | 9.39 | 3.47 | 0.891 | 212 | 10.5 | 411 | 101 | 1.84 |
| **Change** | **2.5** | **-0.02** | **-0.01** | **0.70** | **0.08** | **0.002** | **-16** | **0.1** | **-44** | **2** | **0.08** |

*Each number is based on 50 subsamples with 3 readings per subsample

Table 4. Average HVI data (see Appendix A for acronyms) before and after bale storage for Study 1*, †

| Level | Moisture % | Rd† | Plusb† | Color† | Micronaire | Uniform | Strength, g/tex | Trash, % area† | Length, cm |
|---|---|---|---|---|---|---|---|---|---|
| Before | 6.0 | 75.8 | 8.6 | 31 | 4.4 | 82.0 | 29.9 | 0.36 | 2.774 |
| After | 6.1 | 75.7 | 8.5 | 31 | 4.5 | 83.2 | 29.2 | 0.49 | 2.758 |
| **Change** | **0.1** | **-0.1** | **-0.1** | **0** | **0.01** | **1.2** | **-0.7** | **0.13** | **-0.015** |
| Before | 7.3 | 75.6 | 8.5 | 31 | 4.4 | 82.6 | 29.2 | 0.36 | 2.779 |
| After | 7.9 | 74.7 | 8.9 | 31 | 4.5 | 83.2 | 29.4 | 0.42 | 2.753 |
| **Change** | **0.6** | **-0.9** | **0.4** | **0** | **0.01** | **0.6** | **-0.2** | **0.06** | **-0.025** |
| Before | 8.9 | 75.8 | 8.6 | 31 | 4.5 | 81.8 | 28.9 | 0.42 | 2.764 |
| After | 8.2 | 73.6 | 9.3 | 41 | 4.5 | 83.0 | 29.2 | 0.48 | 2.748 |
| **Change** | **-0.7** | **-2.2** | **0.7** | **10** | **0.00** | **1.2** | **0.3** | **0.06** | **-0.015** |
| Before | 13.9 | 76.0 | 8.5 | 31 | 4.5 | 82.4 | 30.0 | 0.42 | 2.769 |
| After | 11.6 | 70.6 | 10.1 | 42 | 4.5 | 83.2 | 29.0 | 0.50 | 2.748 |
| **Change** | **-2.3** | **-5.4** | **1.6** | **11** | **0.00** | **0.8** | **-1.0** | **0.08** | **-0.020** |
| Before | 15.4 | 76.0 | 8.5 | 31 | 4.5 | 82.2 | 29.2 | 0.42 | 2.764 |
| After | 12.9 | 69.3 | 10.6 | 43 | 4.5 | 82.6 | 29.3 | 0.46 | 2.758 |
| **Change** | **-2.5** | **-6.7** | **2.1** | **12** | **0.00** | **0.4** | **0.1** | **0.04** | **-0.005** |

*"Before" data is the average of 5 subsamples for moisture and 10 for HVI, and "after" data is the average 100 subsamples.

†Larger numbers are less favorable.

Table 5. Moisture before and after storage for Study 2.

| Bale number | Lint moisture, % | | | Water added, kg* | Bale weight, kg | |
|---|---|---|---|---|---|---|
| | Lint flue | Before storage | After storage | | Initial | Final |
| 1 | 4.9 | 12.7 | 8.2 | 18.3 | 235.2 | 225.6 |
| 2 | 4.7 | 10.4 | 7.0 | 12.8 | 224.3 | 219.7 |
| 3 | 4.7 | 12.0 | 7.6 | 17.1 | 234.7 | 224.3 |
| 4 | 4.7 | 8.5 | 6.4 | 8.5 | 224.7 | 222.5 |
| 5 | 4.9 | 4.8 | 6.1 | 0.0 | 205.7 | 208.8 |
| 6 | 4.8 | 7.4 | 6.6 | 5.6 | 217.5 | 217.0 |

*Calculated from difference in lint moisture.

Table 6. Summary of AFIS data **before and after** storage (see Appendix A for acronyms) for Study 2.

| | Initial moisture % | L(w) cm | UQL (w) cm | SFC (w) | L(n) cm | SFC (n) | L 5%, cm | L 2.5%, cm | Fine | IFC | Mat Ratio | Nep/ gm | SCN/ gm | Total dust | Dust/ gm | Trash/ gm | VFM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Before | 12.7 | 2.36 | 2.84 | 9.13 | 1.91 | 26.37 | 3.21 | 3.40 | 181.22 | 3.86 | 0.86 | 279.89 | 11.78 | 394.78 | 338.10 | 56.90 | 1.11 |
| After | 8.2 | 2.31 | 2.82 | 10.26 | 1.83 | 28.98 | 3.18 | 3.38 | 178.60 | 4.22 | 0.85 | 290.20 | 13.41 | 408.46 | 346.57 | 61.90 | 1.29 |
| **Change** | **-4.5** | **-0.05** | **-0.02** | **1.13** | **-0.08** | **2.61** | **-0.03** | **-0.02** | **-2.62** | **0.36** | **-0.01** | **10.31** | **1.63** | **13.68** | **8.47** | **5.00** | **0.18** |
| Before | 12.0 | 2.31 | 2.82 | 10.24 | 1.85 | 28.90 | 3.18 | 3.38 | 179.13 | 4.06 | 0.86 | 281.88 | 11.00 | 435.50 | 371.30 | 64.30 | 1.34 |
| After | 7.6 | 2.29 | 2.79 | 10.83 | 1.80 | 30.08 | 3.15 | 3.35 | 177.16 | 4.32 | 0.85 | 297.60 | 12.74 | 432.68 | 370.71 | 61.90 | 1.25 |
| **Change** | **-4.4** | **-0.02** | **-0.03** | **0.59** | **-0.05** | **1.18** | **-0.03** | **-0.03** | **-1.97** | **0.26** | **-0.01** | **15.72** | **1.74** | **-2.82** | **-0.59** | **-2.40** | **-0.09** |
| Before | 10.4 | 2.34 | 2.82 | 9.71 | 1.88 | 27.49 | 3.19 | 3.38 | 178.67 | 4.14 | 0.85 | 281.00 | 9.89 | 481.56 | 416.90 | 64.70 | 1.31 |
| After | 7.0 | 2.31 | 2.82 | 10.47 | 1.83 | 29.55 | 3.18 | 3.35 | 176.25 | 4.46 | 0.84 | 290.80 | 12.80 | 442.35 | 379.36 | 63.00 | 1.28 |
| **Change** | **-3.4** | **-0.03** | **0.00** | **0.76** | **-0.05** | **2.06** | **-0.01** | **-0.03** | **-2.42** | **0.32** | **-0.01** | **9.80** | **2.91** | **-39.21** | **-37.54** | **-1.70** | **-0.03** |
| Before | 8.5 | 2.31 | 2.79 | 10.17 | 1.83 | 28.89 | 3.16 | 3.35 | 179.22 | 4.16 | 0.85 | 275.67 | 12.22 | 451.89 | 385.70 | 66.10 | 1.20 |
| After | 6.4 | 2.29 | 2.79 | 11.22 | 1.80 | 31.05 | 3.15 | 3.33 | 176.43 | 4.53 | 0.84 | 287.70 | 11.77 | 485.94 | 417.53 | 68.40 | 1.34 |
| **Change** | **-2.1** | **-0.02** | **0.00** | **1.05** | **-0.03** | **2.16** | **-0.01** | **-0.02** | **-2.79** | **0.37** | **-0.01** | **12.03** | **-0.45** | **34.05** | **31.83** | **2.30** | **0.14** |
| Before | 7.4 | 2.31 | 2.79 | 10.43 | 1.83 | 29.45 | 3.14 | 3.35 | 178.25 | 4.40 | 0.85 | 304.50 | 11.25 | 476.13 | 408.50 | 67.60 | 1.29 |
| After | 6.6 | 2.29 | 2.79 | 11.26 | 1.78 | 31.25 | 3.12 | 3.33 | 175.88 | 4.51 | 0.84 | 301.10 | 11.86 | 482.89 | 413.71 | 69.10 | 1.40 |
| **Change** | **-0.8** | **-0.02** | **0.00** | **0.83** | **-0.05** | **1.80** | **-0.02** | **-0.02** | **-2.37** | **0.11** | **-0.01** | **-3.40** | **0.61** | **6.76** | **5.21** | **1.50** | **0.11** |
| Before | 4.8 | 2.31 | 2.82 | 9.76 | 1.85 | 27.94 | 3.17 | 3.35 | 179.00 | 4.17 | 0.85 | 286.67 | 11.56 | 535.22 | 459.90 | 75.20 | 1.54 |
| After | 6.1 | 2.29 | 2.79 | 10.94 | 1.80 | 30.70 | 3.15 | 3.33 | 176.31 | 4.55 | 0.84 | 296.50 | 12.67 | 517.55 | 446.42 | 71.10 | 1.38 |
| **Change** | **1.3** | **-0.02** | **-0.03** | **1.18** | **-0.05** | **2.76** | **-0.02** | **-0.02** | **-2.69** | **0.38** | **-0.01** | **9.83** | **1.11** | **-17.67** | **-13.48** | **-4.10** | **-0.16** |

Table 7. High Volume Instrument classification **before and after** bale storage (see Appendix A for acronyms). Samples were stored in paper bags prior to classification and were conditioned by AMS in accordance with standard practices for Study 2.

| | Initial moisture, % | Rd | Plus b | HVI color | Mike | Strength, g/tex | Leaf | % Area | Length, cm | Uniformity |
|---|---|---|---|---|---|---|---|---|---|---|
| Before | 12.7 | 74.71 | 9.17 | 31 | 4.70 | 27.01 | 2.7 | 0.24 | 2.72 | 81.4 |
| After | 8.2 | 73.53 | 9.51 | 32 | 4.80 | 25.90 | 2.4 | 0.32 | 2.69 | 81.6 |
| **Change** | **-4.5** | **-1.18** | **0.34** | **1** | **0.10** | **-1.11** | **-0.3** | **0.08** | **-0.03** | **0.02** |
| Before | 12.0 | 74.56 | 8.86 | 31 | 4.61 | 26.80 | 2.7 | 0.24 | 2.72 | 81.7 |
| After | 7.6 | 73.06 | 9.61 | 32 | 4.74 | 25.78 | 2.5 | 0.34 | 2.69 | 81.5 |
| **Change** | **-4.4** | **-1.50** | **0.75** | **1** | **0.13** | **-1.02** | **-0.2** | **0.10** | **-0.03** | **-0.02** |
| Before | 10.4 | 74.25 | 9.05 | 31 | 4.58 | 27.55 | 2.9 | 0.29 | 2.72 | 81.8 |
| After | 7.0 | 73.41 | 9.39 | 32 | 4.70 | 25.76 | 2.3 | 0.31 | 2.69 | 81.7 |
| **Change** | **-3.4** | **-0.84** | **0.34** | **1** | **0.12** | **-1.79** | **-0.6** | **0.02** | **-0.03** | **-0.01** |
| Before | 8.5 | 74.33 | 9.02 | 31 | 4.67 | 26.93 | 2.9 | 0.28 | 2.69 | 81.6 |
| After | 6.4 | 74.08 | 9.14 | 31 | 4.75 | 26.07 | 2.6 | 0.34 | 2.69 | 81.6 |
| **Change** | **-2.1** | **-0.25** | **0.12** | **0** | **0.08** | **-0.86** | **-0.3** | **0.06** | **0.00** | **0.0** |
| Before | 7.4 | 73.63 | 9.14 | 31 | 4.65 | 26.93 | 2.8 | 0.31 | 2.69 | 81.6 |
| After | 6.6 | 74.28 | 9.17 | 31 | 4.72 | 26.18 | 2.4 | 0.33 | 2.69 | 81.5 |
| **Change** | **-0.8** | **0.65** | **0.03** | **0** | **0.15** | **-0.75** | **-0.4** | **0.02** | **0.00** | **-0.01** |
| Before | 4.8 | 73.29 | 9.23 | 32 | 4.59 | 27.00 | 3.0 | 0.31 | 2.72 | 81.7 |
| After | 6.1 | 73.95 | 9.27 | 32 | 4.69 | 25.89 | 2.6 | 0.34 | 2.67 | 81.4 |
| **Change** | **1.3** | **0.66** | **0.04** | **0** | **0.10** | **-1.11** | **-0.4** | **0.03** | **-0.05** | **-0.03** |

Table 8. Gin data collected for Study 3. Eleven bales were stored in fully coated, woven polypropylene bags. Gin ID 12 (Bale 1047) was in strip-coated woven polypropylene (control).

| Gin ID | Bale No. | Nozzle hole, cm | Pressure, kPa | Seed cotton weight, kg | Seed, weight, kg | Water added, kg | Initial weight, kg | Final weight, kg | Weight change, kg |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1036 | 0.005 | 82.8 | 635.6 | 349.6 | 9.4 | 209.3 | 207.0 | -2.3 |
| 2 | 1037 | 0.005 | 82.8 | 635.6 | 345.0 | 9.7 | 212.5 | 209.7 | -2.7 |
| 3 | 1038 | 0.005 | 82.8 | 635.6 | 349.6 | 9.7 | 210.7 | 207.9 | -2.7 |
| 4 | 1039 | 0.005 | 51.8 | 681.0 | 372.3 | 9.2 | 224.7 | 222.5 | -2.3 |
| 5 | 1040 | 0.005 | 51.8 | 681.0 | 376.8 | 10.0 | 227.9 | 226.1 | -1.8 |
| 6 | 1041 | 0.005 | 51.8 | 681.0 | 381.4 | 9.6 | 227.5 | 225.6 | -1.8 |
| 7 | 1042 | 0.005 | 117.3 | 681.0 | 354.1 | 12.3 | 222.9 | 219.3 | -3.6 |
| 8 | 1043 | 0.005 | 117.3 | 681.0 | 372.3 | 13.0 | 227.9 | 223.8 | -4.1 |
| 9 | 1044 | 0.005 | 117.3 | 681.0 | 372.3 | 13.0 | 230.2 | 226.1 | -4.1 |
| 10 | 1045 | 0.003 | 193.2 | 681.0 | 363.2 | 6.3 | 216.6 | 215.2 | -1.4 |
| 11 | 1046 | 0.003 | 193.2 | 681.0 | 363.2 | 6.3 | 217.0 | 216.1 | -0.9 |
| 12 | 1047 | 0.003 | 193.2 | 681.0 | 376.8 | 6.6 | 220.2 | 218.4 | -1.8 |

Table 9. Moisture levels measured for Study 3. Eleven bales were stored in fully coated, woven polypropylene bags. Gin ID 12 (Bale 1047) was in strip-coated woven polypropylene (control).

| Gin ID | Wagon moisture, % | Lint moisture, % | | |
|---|---|---|---|---|
| | | At condenser | In bale | After storage |
| 1 | 9.6 | 4.9 | 9.4 | 8.2 |
| 2 | 9.0 | 5.0 | 9.7 | 8.4 |
| 3 | 8.9 | 5.0 | 9.6 | 8.2 |
| 4 | 10.1 | 4.9 | 9.0 | 7.8 |
| 5 | 9.6 | 4.8 | 9.0 | 7.8 |
| 6 | 9.5 | 5.1 | 9.0 | 7.9 |
| 7 | 9.8 | 5.1 | 10.5 | 8.6 |
| 8 | 9.3 | 5.1 | 10.7 | 8.5 |
| 9 | 9.7 | 5.2 | 10.8 | 8.9 |
| 10 | 9.6 | 5.2 | 8.1 | 7.4 |
| 11 | 8.6 | 5.3 | 8.0 | 7.2 |
| 12 | 8.9 | 5.0 | 7.8 | 6.6 |

Table 10. HVI data **before and after** storage (see Appendix A for acronyms) for Study 3. Samples were conditioned by AMS in accordance with standard practices. Eleven bales were stored in fully coated, woven polypropylene bags. Gin ID 12 (control)was stored in strip-coated woven polypropylene.

| | Gin ID | Moisture, % | Mike | Strength, g/tex | Rd | Plus b | Leaf | % Area | Length, cm | Uniform | Color |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Before | 1 | 9.4 | 4.60 | 26.48 | 76.50 | 9.00 | 3.90 | 0.040 | 2.682 | 82.00 | 31 |
| After | 1 | 8.2 | 4.68 | 26.98 | 73.02 | 10.05 | 3.88 | 0.045 | 2.715 | 82.38 | 32 |
| **Change** | | **-1.2** | **0.08** | **0.50** | **-3.48** | **1.05** | **-0.02** | **0.005** | **0.033** | **0.38** | **1** |
| Before | 2 | 9.7 | 4.46 | 26.53 | 77.10 | 9.17 | 4.20 | 0.039 | 2.654 | 82.10 | 21 |
| After | 2 | 8.4 | 4.61 | 27.25 | 72.96 | 9.89 | 3.89 | 0.046 | 2.723 | 82.52 | 32 |
| **Change** | | **-1.3** | **0.15** | **0.72** | **-4.14** | **0.72** | **-0.31** | **0.007** | **0.069** | **0.42** | **11** |
| Before | 3 | 9.6 | 4.47 | 25.97 | 76.40 | 9.17 | 4.10 | 0.041 | 2.659 | 81.80 | 31 |
| After | 3 | 8.2 | 4.60 | 27.22 | 72.25 | 9.95 | 3.98 | 0.048 | 2.723 | 82.59 | 32 |
| **Change** | | **-1.4** | **0.13** | **1.25** | **-4.15** | **0.78** | **-0.12** | **0.007** | **0.064** | **0.79** | **1** |
| Before | 4 | 9.0 | 4.42 | 26.10 | 75.40 | 9.32 | 4.10 | 0.041 | 2.652 | 81.90 | 31 |
| After | 4 | 7.8 | 4.63 | 27.07 | 73.32 | 9.86 | 3.84 | 0.043 | 2.723 | 82.70 | 32 |
| **Change** | | **-1.2** | **0.21** | **0.97** | **-2.08** | **0.54** | **-0.26** | **0.002** | **0.071** | **0.80** | **1** |
| Before | 5 | 9.0 | 4.57 | 26.23 | 76.80 | 9.09 | 3.90 | 0.043 | 2.664 | 82.00 | 31 |
| After | 5 | 7.8 | 4.73 | 27.24 | 75.26 | 9.73 | 3.97 | 0.041 | 2.738 | 82.80 | 32 |
| **Change** | | **-1.2** | **0.16** | **1.01** | **-1.54** | **0.64** | **0.07** | **-0.002** | **0.074** | **0.80** | **1** |
| Before | 6 | 9.0 | 4.46 | 25.87 | 75.60 | 9.22 | 4.10 | 0.044 | 2.675 | 81.80 | 31 |
| After | 6 | 7.9 | 4.63 | 26.93 | 73.32 | 9.89 | 4.09 | 0.049 | 2.733 | 82.87 | 32 |
| **Change** | | **-1.1** | **0.17** | **1.06** | **-2.28** | **0.67** | **-0.01** | **0.005** | **0.058** | **1.07** | **1** |
| Before | 7 | 10.5 | 4.42 | 26.20 | 76.90 | 9.31 | 4.10 | 0.041 | 2.667 | 81.90 | 21 |
| After | 7 | 8.6 | 4.67 | 27.19 | 71.53 | 10.40 | 4.04 | 0.054 | 2.748 | 82.92 | 32 |
| **Change** | | **-1.9** | **0.25** | **0.99** | **-5.37** | **1.09** | **-0.06** | **0.013** | **0.081** | **1.02** | **11** |
| Before | 8 | 10.7 | 4.37 | 26.08 | 76.50 | 9.20 | 4.20 | 0.042 | 2.654 | 82.30 | 31 |
| After | 8 | 8.5 | 4.62 | 27.00 | 71.06 | 10.41 | 4.05 | 0.056 | 2.731 | 82.64 | 32 |
| **Change** | | **-2.2** | **0.25** | **0.92** | **-5.44** | **1.21** | **-0.15** | **0.014** | **0.077** | **0.34** | **1** |
| Before | 9 | 10.8 | 4.53 | 26.36 | 75.90 | 9.01 | 4.30 | 0.046 | 2.672 | 82.20 | 31 |
| After | 9 | 8.9 | 4.64 | 27.35 | 70.04 | 10.61 | 4.25 | 0.067 | 2.731 | 82.70 | 43 |
| **Change** | | **-1.9** | **0.11** | **0.99** | **-5.86** | **1.60** | **-0.05** | **0.021** | **0.059** | **0.50** | **12** |
| Before | 10 | 8.1 | 4.46 | 26.57 | 74.70 | 9.25 | 4.30 | 0.050 | 2.659 | 81.70 | 31 |
| After | 10 | 7.4 | 4.60 | 26.97 | 73.68 | 9.78 | 4.14 | 0.054 | 2.710 | 82.48 | 32 |
| **Change** | | **-0.7** | **0.14** | **0.40** | **-1.02** | **0.53** | **-0.16** | **0.004** | **0.051** | **0.78** | **1** |
| Before | 11 | 8.0 | 4.47 | 26.08 | 75.70 | 9.28 | 4.50 | 0.045 | 2.644 | 82.00 | 31 |
| After | 11 | 7.2 | 4.62 | 26.53 | 74.56 | 9.64 | 4.07 | 0.049 | 2.692 | 82.55 | 32 |
| **Change** | | **-0.8** | **0.15** | **0.45** | **-1.14** | **0.36** | **-0.43** | **0.004** | **0.048** | **0.55** | **1** |
| Before | 12 | 7.8 | 4.51 | 26.26 | 76.00 | 9.07 | 4.40 | 0.043 | 2.654 | 82.10 | 31 |
| After | 12 | 6.6 | 4.63 | 26.57 | 74.92 | 9.60 | 4.08 | 0.047 | 2.703 | 82.42 | 32 |
| **Change** | | **-1.2** | **0.12** | **0.31** | **-1.08** | **0.53** | **-0.32** | **0.004** | **0.049** | **0.32** | **1** |

Table 11. Analyses of variance for the change in HVI properties factors during storage for Study 3 (see Appendix A for acronyms).

| Source of variation | DF | Means squares for Mike change | Strength change | Rd change | Plusb change | Leaf change |
|---|---|---|---|---|---|---|
| Moisture | 4 | 0.034** | 1.855** | 90.438** | 2.945** | 0.259** |
| Error | | 0.004 | 0.168 | 0.636 | 0.038 | 0.039 |
| | | | | | | |
| Mean | | 0.159 | 0.797 | -3.129 | 0.5800 | -0.153 |
| MSE | | 0.062 | 0.409 | 0.797 | 0.195 | 0.198 |
| CV | | 39.081 | 51.36 | -25.478 | 23.99 | -129.775 |
| R-Square | | 0.232 | 0.278 | 0.832 | 0.730 | 0.187 |

| Source of variation | DF | Means squares for % Area change x $10^3$ | Color change | Length Change x $10^3$ | Uniformity change |
|---|---|---|---|---|---|
| Moisture | 4 | 0.875** | 350.273** | 0.426** | 0.808** |
| Error | | 0.037 | 14.950 | 0.040 | 0.091 |
| | | | | | |
| Mean | | 0.0068 | 3.675 | 0.024 | 0.649 |
| MSE | | 0.0061 | 3.867 | 0.006 | 0.302 |
| CV | | 89.126 | 105.211 | 26.573 | 46.563 |
| R-Square | | 0.452 | 0.449 | 0.269 | 0.235 |

Table 12. HVI data before and after storage (see Appendix A for acronyms) and the initial final change by moisture treatment for Study 3. Eleven bales were stored in fully coated, woven polypropylene bags. The 7.8% moisture bale (control) was stored in strip-coated woven polypropylene*.

| Level | Moisture, % | Mike | Strength, g/tex | Rd | Plus b | Leaf | % Area | Length, cm | Uniformity | Mode color |
|---|---|---|---|---|---|---|---|---|---|---|
| Before | 10.70 | 4.44 | 26.21 | 76.43 | 9.17 | 4.20 | 0.043 | 2.664 | 82.13 | 31 |
| After | 8.70 | 4.64 | 27.18 | 70.88 | 10.47 | 4.22 | 0.059 | 2.736 | 82.75 | 32 |
| **Change** | **-2.00d** | **0.20a** | **0.97a** | **-5.55d** | **1.30a** | **0.02a** | **0.016a** | **0.072a** | **0.62b** | **1a** |
| Before | 9.60 | 4.51 | 26.33 | 76.67 | 9.11 | 4.07 | 0.040 | 2.664 | 81.97 | 31 |
| After | 8.20 | 4.63 | 27.16 | 72.73 | 9.96 | 3.92 | 0.046 | 2.720 | 82.50 | 32 |
| **Change** | **-1.40c** | **0.12c** | **0.83a** | **-3.94c** | **0.85b** | **-0.15a** | **0.006b** | **0.056b** | **0.53b** | **1a** |
| Before | 9.00 | 4.48 | 26.07 | 75.93 | 9.21 | 4.03 | 0.043 | 2.664 | 81.90 | 31 |
| After | 7.90 | 4.66 | 27.08 | 73.97 | 9.83 | 3.97 | 0.044 | 2.731 | 82.79 | 32 |
| **Change** | **-1.10b** | **0.18ab** | **1.01a** | **-1.96b** | **0.62c** | **-0.06a** | **0.001c** | **0.067a** | **0.89a** | **1a** |
| Before | 8.10 | 4.47 | 26.33 | 75.2 | 9.27 | 4.40 | 0.048 | 2.652 | 81.85 | 31 |
| After | 7.30 | 4.61 | 26.75 | 74.12 | 9.71 | 4.11 | 0.051 | 2.700 | 82.51 | 32 |
| **Change** | **-0.80a** | **0.14bc** | **0.42b** | **-1.08a** | **0.44d** | **-0.29b** | **0.003bc** | **0.048b** | **0.66b** | **1a** |
| Before | 7.80 | 4.51 | 26.26 | 76.00 | 9.07 | 4.40 | 0.043 | 2.654 | 82.10 | 31 |
| After | 6.60 | 4.63 | 26.57 | 74.92 | 9.60 | 4.08 | 0.047 | 2.703 | 82.42 | 32 |
| **Change** | **-1.20b** | **0.12c** | **0.31b** | **-1.08a** | **0.53cd** | **-0.32b** | **0.004bc** | **0.049b** | **0.32c** | **1a** |

*Means in bold in each column not followed by the same lower case letter are significant at the 5% level as judged by the Waller-Duncan Test.

Table 13 HVI properties (see Appendix A for acronyms) at each layer of cotton after 188 days of bale storage at declining moisture levels for Study 3. Eleven bales were stored in fully coated, woven polypropylene bags. Gin ID 12 (7.8% moisture) was in strip-coated woven polypropylene. The 7.8% moisture bale (control) was in strip-coated woven polypropylene.

| Initial moisture, % | Layer | Mike | Strength, g/tex | Rd | Plus b | Leaf | % Area | Length, cm | Uniform | Color |
|---|---|---|---|---|---|---|---|---|---|---|
| 10.7 | 0 | 4.61 | 27.11 | 70.73 | 10.67 | 4.03 | 0.056 | 2.731 | 82.67 | 33 |
| | 1 | 4.67 | 27.10 | 71.17 | 10.59 | 4.17 | 0.055 | 2.725 | 82.67 | 32 |
| | 2 | 4.66 | 27.00 | 70.40 | 10.55 | 4.37 | 0.068 | 2.738 | 82.73 | 43 |
| | 3 | 4.67 | 27.20 | 70.80 | 10.42 | 4.17 | 0.060 | 2.741 | 82.90 | 43 |
| | 4 | 4.65 | 27.32 | 71.00 | 10.46 | 4.20 | 0.062 | 2.738 | 82.83 | 32 |
| | 5 | 4.64 | 27.10 | 71.03 | 10.42 | 4.17 | 0.061 | 2.743 | 82.67 | 32 |
| | 6 | 4.67 | 27.25 | 71.10 | 10.47 | 4.03 | 0.056 | 2.743 | 82.73 | 32 |
| | 7 | 4.68 | 27.09 | 70.63 | 10.43 | 4.03 | 0.055 | 2.738 | 82.80 | 43 |
| | 8 | 4.60 | 27.42 | 70.53 | 10.38 | 4.03 | 0.058 | 2.733 | 82.83 | 32 |
| | 9 | 4.58 | 27.19 | 71.37 | 10.34 | 3.93 | 0.057 | 2.731 | 82.70 | 32 |
| 9.6 | 0 | 4.60 | 27.03 | 71.96 | 10.26 | 3.77 | 0.043 | 2.723 | 82.42 | 32 |
| | 1 | 4.64 | 27.39 | 72.10 | 9.98 | 3.93 | 0.048 | 2.705 | 82.27 | 32 |
| | 2 | 4.62 | 27.28 | 72.00 | 9.98 | 3.93 | 0.049 | 2.715 | 82.40 | 32 |
| | 3 | 4.60 | 27.12 | 71.97 | 10.02 | 4.03 | 0.051 | 2.713 | 82.47 | 32 |
| | 4 | 4.65 | 27.26 | 72.50 | 9.95 | 3.93 | 0.046 | 2.723 | 82.43 | 32 |
| | 5 | 4.61 | 26.90 | 72.73 | 9.94 | 4.03 | 0.048 | 2.718 | 82.70 | 32 |
| | 6 | 4.62 | 26.99 | 73.14 | 9.92 | 4.00 | 0.044 | 2.723 | 82.38 | 32 |
| | 7 | 4.63 | 27.36 | 73.66 | 9.85 | 3.76 | 0.043 | 2.736 | 82.69 | 32 |
| | 8 | 4.67 | 27.15 | 73.93 | 9.82 | 3.86 | 0.044 | 2.723 | 82.57 | 32 |
| | 9 | 4.64 | 27.04 | 73.44 | 9.94 | 3.89 | 0.046 | 2.725 | 82.70 | 32 |
| 9.0 | 0 | 4.71 | 26.94 | 74.80 | 9.91 | 3.93 | 0.039 | 2.741 | 82.93 | 32 |
| | 1 | 4.71 | 26.77 | 74.40 | 9.82 | 3.90 | 0.042 | 2.731 | 83.00 | 32 |
| | 2 | 4.68 | 27.05 | 73.43 | 9.79 | 4.03 | 0.046 | 2.733 | 82.87 | 32 |
| | 3 | 4.68 | 27.32 | 73.53 | 9.83 | 4.00 | 0.046 | 2.736 | 82.90 | 32 |
| | 4 | 4.68 | 26.92 | 73.57 | 9.83 | 4.03 | 0.045 | 2.733 | 82.80 | 32 |
| | 5 | 4.61 | 27.09 | 73.57 | 10.00 | 3.97 | 0.050 | 2.713 | 82.70 | 32 |
| | 6 | 4.62 | 27.38 | 73.70 | 9.84 | 4.03 | 0.046 | 2.731 | 82.77 | 32 |
| | 7 | 4.61 | 27.15 | 73.93 | 9.78 | 3.97 | 0.046 | 2.733 | 82.67 | 32 |
| | 8 | 4.64 | 27.35 | 73.90 | 9.74 | 3.93 | 0.042 | 2.733 | 82.63 | 32 |
| | 9 | 4.66 | 26.80 | 74.83 | 9.72 | 3.87 | 0.041 | 2.728 | 82.63 | 32 |
| 8.1 | 0 | 4.60 | 26.99 | 74.85 | 9.71 | 3.95 | 0.043 | 2.710 | 82.85 | 32 |
| | 1 | 4.66 | 26.91 | 74.50 | 9.80 | 4.05 | 0.048 | 2.713 | 82.65 | 32 |

Table 13 HVI properties (see Appendix A for acronyms) at each layer of cotton after 188 days of bale storage at declining moisture levels for Study 3. Eleven bales were stored in fully coated, woven polypropylene bags. Gin ID 12 (7.8% moisture) was in strip-coated woven polypropylene. The 7.8% moisture bale (control) was in strip-coated woven polypropylene – continued.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.1 | 2 | 4.64 | 26.52 | 74.75 | 9.83 | 4.10 | 0.049 | 2.690 | 82.40 | 32 |
| | 3 | 4.66 | 26.74 | 74.45 | 9.72 | 4.15 | 0.053 | 2.695 | 82.40 | 32 |
| | 4 | 4.63 | 26.56 | 73.90 | 9.58 | 4.15 | 0.052 | 2.708 | 82.75 | 32 |
| | 5 | 4.57 | 26.65 | 73.60 | 9.69 | 4.10 | 0.055 | 2.700 | 82.35 | 32 |
| | 6 | 4.65 | 26.73 | 73.90 | 9.74 | 4.00 | 0.051 | 2.708 | 82.25 | 32 |
| | 7 | 4.60 | 27.08 | 73.50 | 9.72 | 4.25 | 0.058 | 2.708 | 82.70 | 32 |
| | 8 | 4.57 | 26.92 | 73.95 | 9.69 | 4.25 | 0.053 | 2.692 | 82.60 | 32 |
| | 9 | 4.55 | 26.42 | 73.80 | 9.65 | 4.05 | 0.053 | 2.687 | 82.20 | 32 |
| 7.8 | 0 | 4.56 | 26.27 | 76.00 | 9.53 | 4.10 | 0.045 | 2.690 | 82.50 | 31 |
| | 1 | 4.59 | 26.40 | 75.50 | 9.52 | 4.10 | 0.043 | 2.697 | 82.20 | 32 |
| | 2 | 4.62 | 26.53 | 75.20 | 9.52 | 4.00 | 0.050 | 2.690 | 82.70 | 31 |
| | 3 | 4.62 | 26.58 | 75.10 | 9.53 | 4.10 | 0.043 | 2.692 | 82.50 | 32 |
| | 4 | 4.63 | 27.43 | 76.10 | 9.57 | 4.00 | 0.045 | 2.720 | 82.20 | 31 |
| | 5 | 4.59 | 26.92 | 73.90 | 9.67 | 4.10 | 0.048 | 2.708 | 82.60 | 32 |
| | 6 | 4.66 | 26.66 | 74.10 | 9.74 | 4.20 | 0.058 | 2.690 | 82.10 | 32 |
| | 7 | 4.70 | 25.89 | 73.40 | 9.74 | 4.10 | 0.051 | 2.708 | 82.50 | 32 |
| | 8 | 4.62 | 26.50 | 74.40 | 9.55 | 4.20 | 0.047 | 2.713 | 82.40 | 32 |
| | 9 | 4.71 | 26.51 | 75.50 | 9.64 | 3.90 | 0.040 | 2.705 | 82.50 | 32 |

Table 14. Summary of AFIS data before and after storage (see Appendix A for acronyms) for Study 3 for 188 days.

| | Gin ID | Moisture, % | L(w), cm | L(w) cv cm | UQL (w) cm | SFC (w) | L(n) cm | L(n) cv | SFC (n) | L 5%, cm | L2.5%, cm | Fine |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Before | 1 | 9.4 | 2.35 | 83.26 | 2.8 | 8.94 | 1.91 | 48.92 | 26.58 | 3.18 | 3.38 | 176.6 |
| After | 1 | 8.2 | 2.35 | 83.16 | 2.8 | 8.82 | 1.91 | 48.45 | 26.08 | 3.18 | 3.38 | 176.6 |
| **Change** | | **-1.2** | **0.00** | **-0.10** | **0.0** | **-0.12** | **0.00** | **-0.47** | **-0.50** | **0.00** | **0.00** | **0.0** |
| Before | 2 | 9.7 | 2.35 | 82.65 | 2.8 | 8.74 | 1.91 | 48.68 | 26.14 | 3.18 | 3.38 | 175.6 |
| After | 2 | 8.4 | 2.34 | 82.73 | 2.8 | 8.82 | 1.91 | 48.46 | 26.15 | 3.18 | 3.38 | 175.2 |
| **Change** | | **-1.3** | **-0.01** | **0.08** | **0.0** | **0.08** | **0.00** | **-0.22** | **0.01** | **0.00** | **0.00** | **-0.4** |
| Before | 3 | 9.6 | 2.32 | 83.01 | 2.8 | 9.32 | 1.85 | 49.14 | 27.30 | 3.15 | 3.33 | 173.6 |
| After | 3 | 8.2 | 2.31 | 84.40 | 2.8 | 9.48 | 1.85 | 49.49 | 27.65 | 3.15 | 3.35 | 173.4 |
| **Change** | | **-1.4** | **-0.01** | **1.39** | **0.0** | **0.16** | **0.00** | **0.35** | **0.35** | **0.00** | **0.02** | **-0.2** |
| Before | 4 | 9.0 | 2.33 | 83.06 | 2.8 | 9.14 | 1.88 | 49.32 | 27.10 | 3.18 | 3.35 | 175.2 |
| After | 4 | 7.8 | 2.32 | 84.51 | 2.8 | 9.44 | 1.88 | 49.60 | 27.58 | 3.15 | 3.38 | 174.4 |
| **Change** | | **-1.2** | **-0.01** | **1.45** | **0.0** | **0.30** | **0.00** | **0.28** | **0.48** | **-0.03** | **0.03** | **-0.8** |
| Before | 5 | 9.0 | 2.36 | 82.80 | 2.8 | 8.70 | 1.91 | 48.42 | 25.94 | 3.18 | 3.38 | 176.4 |
| After | 5 | 7.8 | 2.35 | 82.96 | 2.8 | 8.77 | 1.91 | 48.49 | 26.06 | 3.18 | 3.38 | 175.2 |
| **Change** | | **-1.2** | **-0.01** | **0.16** | **0.0** | **0.07** | **0.00** | **0.07** | **0.12** | **0.00** | **0.00** | **-1.2** |
| Before | 6 | 9.0 | 2.33 | 83.87 | 2.8 | 9.22 | 1.88 | 49.36 | 27.14 | 3.18 | 3.38 | 174.0 |
| After | 6 | 7.9 | 2.33 | 83.82 | 2.8 | 9.23 | 1.88 | 49.06 | 27.01 | 3.18 | 3.38 | 173.8 |
| **Change** | | **-1.1** | **0.00** | **-0.05** | **0.0** | **0.01** | **0.00** | **-0.30** | **-0.13** | **0.00** | **0.00** | **-0.2** |
| Before | 7 | 10.5 | 2.38 | 80.57 | 2.8 | 7.82 | 1.96 | 46.06 | 23.42 | 3.20 | 3.38 | 177.0 |
| After | 7 | 8.6 | 2.37 | 80.70 | 2.8 | 8.08 | 1.96 | 46.50 | 24.05 | 3.18 | 3.38 | 176.4 |
| **Change** | | **-1.9** | **-0.01** | **0.13** | **0.0** | **0.26** | **0.00** | **0.44** | **0.63** | **-0.02** | **0.00** | **-0.6** |
| Before | 8 | 10.7 | 2.37 | 81.53 | 2.8 | 8.06 | 1.96 | 46.52 | 23.90 | 3.20 | 3.40 | 175.8 |
| After | 8 | 8.5 | 2.36 | 81.86 | 2.8 | 8.31 | 1.93 | 47.03 | 24.58 | 3.18 | 3.38 | 175.7 |
| **Change** | | **-2.2** | **-0.01** | **0.33** | **0.0** | **0.25** | **-0.03** | **0.51** | **0.68** | **-0.02** | **-0.02** | **-0.1** |
| Before | 9 | 10.8 | 2.35 | 80.57 | 2.8 | 8.24 | 1.93 | 46.92 | 24.56 | 3.18 | 3.38 | 176.4 |
| After | 9 | 8.9 | 2.36 | 81.53 | 2.8 | 8.24 | 1.93 | 46.95 | 24.45 | 3.18 | 3.40 | 175.3 |
| **Change** | | **-1.9** | **0.01** | **0.96** | **0.0** | **0.00** | **0.00** | **0.03** | **-0.11** | **0.00** | **0.02** | **-1.1** |
| Before | 10 | 8.1 | 2.31 | 84.73 | 2.8 | 9.54 | 1.85 | 49.74 | 27.76 | 3.15 | 3.33 | 174.0 |
| After | 10 | 7.4 | 2.31 | 85.19 | 2.8 | 9.68 | 1.85 | 50.14 | 28.34 | 3.15 | 3.35 | 173.7 |
| **Change** | | **-0.7** | **0.00** | **0.46** | **0.0** | **0.14** | **0.00** | **0.40** | **0.58** | **0.00** | **0.02** | **-0.3** |
| Before | 11 | 8.0 | 2.31 | 83.97 | 2.8 | 9.34 | 1.85 | 49.58 | 27.72 | 3.12 | 3.33 | 175.0 |
| After | 11 | 7.2 | 2.30 | 85.98 | 2.8 | 9.85 | 1.83 | 50.65 | 28.97 | 3.15 | 3.35 | 173.3 |
| **Change** | | **-0.8** | **-0.01** | **2.01** | **0.0** | **0.51** | **-0.02** | **1.07** | **1.25** | **0.03** | **0.02** | **-1.7** |
| Before | 12 | 7.8 | 2.33 | 84.43 | 2.8 | 9.16 | 1.88 | 49.38 | 27.16 | 3.15 | 3.35 | 175.4 |
| After | 12 | 6.6 | 2.32 | 84.48 | 2.8 | 9.45 | 1.85 | 49.56 | 27.74 | 3.15 | 3.35 | 174.8 |
| **Change** | | **-1.2** | **-0.01** | **0.05** | **0.0** | **0.29** | **-0.03** | **0.18** | **0.58** | **0.00** | **0.00** | **-0.6** |

Table 14. Summary of AFIS data before and after storage for Study 3 for 188 days – continued.

| | Gin ID | Moisture, % | IFC | Mat ratio | Nep size | Nep, gm | SCN, size | SCN, gm | Total | Mean size | Dust, gm | Trash, gm | VFM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Before | 1 | 9.4 | 2.35 | 83.26 | 2.8 | 8.9 | 1.9 | 48.9 | 26.6 | 3.2 | 3.4 | 176.6 | 9.4 |
| After | 1 | 8.2 | 2.35 | 83.16 | 2.8 | 8.8 | 1.9 | 48.5 | 26.1 | 3.2 | 3.4 | 176.6 | 8.2 |
| **Change** | | **-1.2** | **0.00** | **-0.10** | **0.0** | **-0.1** | **0.0** | **-0.5** | **-0.5** | **0.0** | **0.0** | **0.0** | **-1.2** |
| Before | 2 | 9.7 | 2.35 | 82.65 | 2.8 | 8.7 | 1.9 | 48.7 | 26.1 | 3.2 | 3.4 | 175.6 | 9.7 |
| After | 2 | 8.4 | 2.34 | 82.73 | 2.8 | 8.8 | 1.9 | 48.5 | 26.2 | 3.2 | 3.4 | 175.2 | 8.4 |
| **Change** | | **-1.3** | **-0.01** | **0.08** | **0.0** | **0.1** | **0.0** | **-0.2** | **0.0** | **0.0** | **0.0** | **-0.4** | **-1.3** |
| Before | 3 | 9.6 | 2.32 | 83.01 | 2.8 | 9.3 | 1.9 | 49.1 | 27.3 | 3.2 | 3.3 | 173.6 | 9.6 |
| After | 3 | 8.2 | 2.31 | 84.40 | 2.8 | 9.5 | 1.9 | 49.5 | 27.7 | 3.2 | 3.4 | 173.4 | 8.2 |
| **Change** | | **-1.4** | **-0.01** | **1.39** | **0.0** | **0.2** | **0.0** | **0.4** | **0.3** | **0.0** | **0.0** | **-0.2** | **-1.4** |
| Before | 4 | 9.0 | 2.33 | 83.06 | 2.8 | 9.1 | 1.9 | 49.3 | 27.1 | 3.2 | 3.4 | 175.2 | 9.0 |
| After | 4 | 7.8 | 2.32 | 84.51 | 2.8 | 9.4 | 1.9 | 49.6 | 27.6 | 3.2 | 3.4 | 174.4 | 7.8 |
| **Change** | | **-1.2** | **-0.01** | **1.45** | **0.0** | **0.3** | **0.0** | **0.3** | **0.5** | **0.0** | **0.0** | **-0.8** | **-1.2** |
| Before | 5 | 9.0 | 2.36 | 82.80 | 2.8 | 8.7 | 1.9 | 48.4 | 25.9 | 3.2 | 3.4 | 176.4 | 9.0 |
| After | 5 | 7.8 | 2.35 | 82.96 | 2.8 | 8.8 | 1.9 | 48.5 | 26.1 | 3.2 | 3.4 | 175.2 | 7.8 |
| **Change** | | **-1.2** | **-0.01** | **0.16** | **0.0** | **0.1** | **0.0** | **0.1** | **0.1** | **0.0** | **0.0** | **-1.2** | **-1.2** |
| Before | 6 | 9.0 | 2.33 | 83.87 | 2.8 | 9.2 | 1.9 | 49.4 | 27.1 | 3.2 | 3.4 | 174.0 | 9.0 |
| After | 6 | 7.9 | 2.33 | 83.82 | 2.8 | 9.2 | 1.9 | 49.1 | 27.0 | 3.2 | 3.4 | 173.8 | 7.9 |
| **Change** | | **-1.1** | **0.00** | **-0.05** | **0.0** | **0.0** | **0.0** | **-0.3** | **-0.1** | **0.0** | **0.0** | **-0.2** | **-1.1** |
| Before | 7 | 10.5 | 2.38 | 80.57 | 2.8 | 7.8 | 2.0 | 46.1 | 23.4 | 3.2 | 3.4 | 177.0 | 10.5 |
| After | 7 | 8.6 | 2.37 | 80.70 | 2.8 | 8.1 | 2.0 | 46.5 | 24.1 | 3.2 | 3.4 | 176.4 | 8.6 |
| **Change** | | **-1.9** | **-0.01** | **0.13** | **0.0** | **0.3** | **0.0** | **0.4** | **0.6** | **0.0** | **0.0** | **-0.6** | **-1.9** |
| Before | 8 | 10.7 | 2.37 | 81.53 | 2.8 | 8.1 | 2.0 | 46.5 | 23.9 | 3.2 | 3.4 | 175.8 | 10.7 |
| After | 8 | 8.5 | 2.36 | 81.86 | 2.8 | 8.3 | 1.9 | 47.0 | 24.6 | 3.2 | 3.4 | 175.7 | 8.5 |
| **Change** | | **-2.2** | **-0.01** | **0.33** | **0.0** | **0.3** | **0.0** | **0.5** | **0.7** | **0.0** | **0.0** | **-0.1** | **-2.2** |
| Before | 9 | 10.8 | 2.35 | 80.57 | 2.8 | 8.2 | 1.9 | 46.9 | 24.6 | 3.2 | 3.4 | 176.4 | 10.8 |
| After | 9 | 8.9 | 2.36 | 81.53 | 2.8 | 8.2 | 1.9 | 47.0 | 24.5 | 3.2 | 3.4 | 175.3 | 8.9 |
| **Change** | | **-1.9** | **0.01** | **0.96** | **0.0** | **0.0** | **0.0** | **0.0** | **-0.1** | **0.0** | **0.0** | **-1.1** | **-1.9** |
| Before | 10 | 8.1 | 2.31 | 84.73 | 2.8 | 9.5 | 1.9 | 49.7 | 27.8 | 3.2 | 3.3 | 174.0 | 8.1 |
| After | 10 | 7.4 | 2.31 | 85.19 | 2.8 | 9.7 | 1.9 | 50.1 | 28.3 | 3.2 | 3.4 | 173.7 | 7.4 |
| **Change** | | **-0.7** | **0.00** | **0.46** | **0.0** | **0.1** | **0.0** | **0.4** | **0.6** | **0.0** | **0.0** | **-0.3** | **-0.7** |
| Before | 11 | 8.0 | 2.31 | 83.97 | 2.8 | 9.3 | 1.9 | 49.6 | 27.7 | 3.1 | 3.3 | 175.0 | 8.0 |
| After | 11 | 7.2 | 2.30 | 85.98 | 2.8 | 9.9 | 1.8 | 50.7 | 29.0 | 3.2 | 3.4 | 173.3 | 7.2 |
| **Change** | | **-0.8** | **-0.01** | **2.01** | **0.0** | **0.5** | **0.0** | **1.1** | **1.3** | **0.0** | **0.0** | **-1.7** | **-0.8** |
| Before | 12 | 7.8 | 2.33 | 84.43 | 2.8 | 9.2 | 1.9 | 49.4 | 27.2 | 3.2 | 3.4 | 175.4 | 7.8 |
| After | 12 | 6.6 | 2.32 | 84.48 | 2.8 | 9.5 | 1.9 | 49.6 | 27.7 | 3.2 | 3.4 | 174.8 | 6.6 |
| **Change** | | **-1.2** | **-0.01** | **0.05** | **0.0** | **0.3** | **0.0** | **0.2** | **0.6** | **0.0** | **0.0** | **-0.6** | **-1.2** |

Figure 1. Moisture was sprayed on the cotton with a series of nozzles as the cotton came down the lint slide for Studies 1, 2, and 3.


Figure 2. Typical bale divided into 10 layers about 6.4 cm (2.5-inches) apart before sampling.

Figure 3.  Layer of cotton “pulled back” for sampling.

Figure 4.  Five bales stored in triple polyethylene bags for 116 days under ambient conditions for Study 1

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Figure 5.  Bales stored near bale press for Study 2.


Figure 6.  Bales for Study 3 stored near the instrument room in Building 21.
Eleven bales were stored in fully coated, woven polypropylene bags.

Figure 7. Water damage for one bale. Dark discoloration indicates organism growth as a result of high moisture storage condition for Study 1.

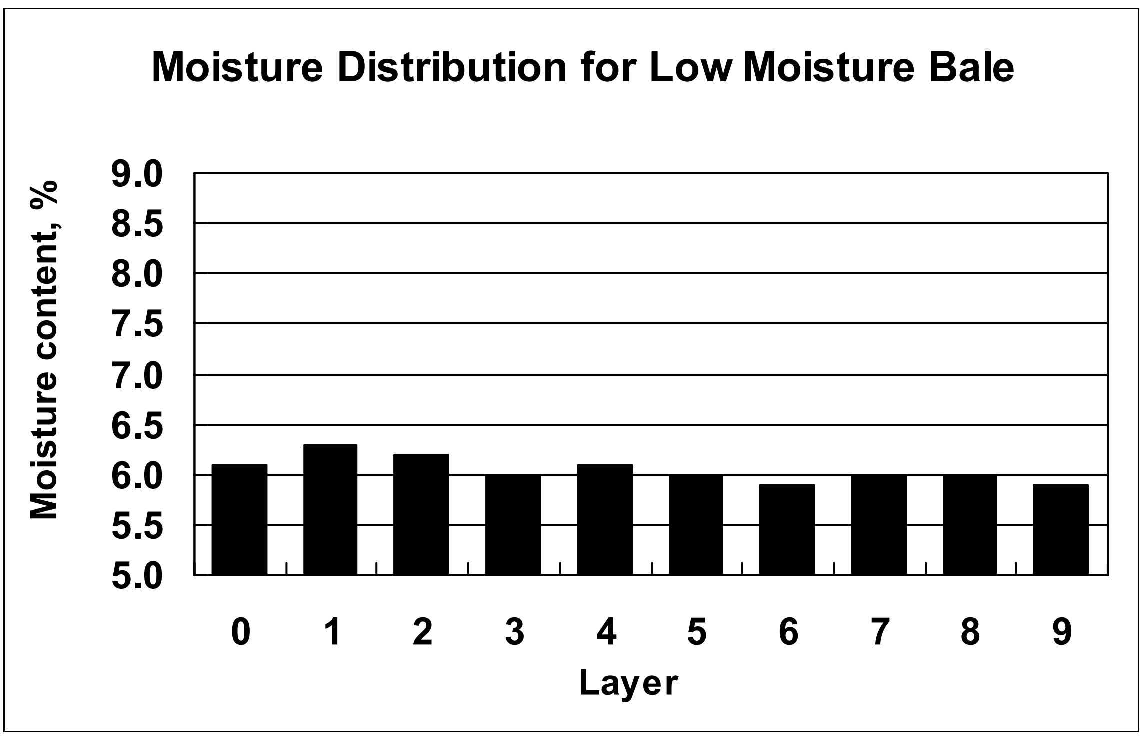


Figure 8. Average moisture at each of the 10 locations within the bale beginning about 7.62 cm (3-inches) from the exterior for Study 1.

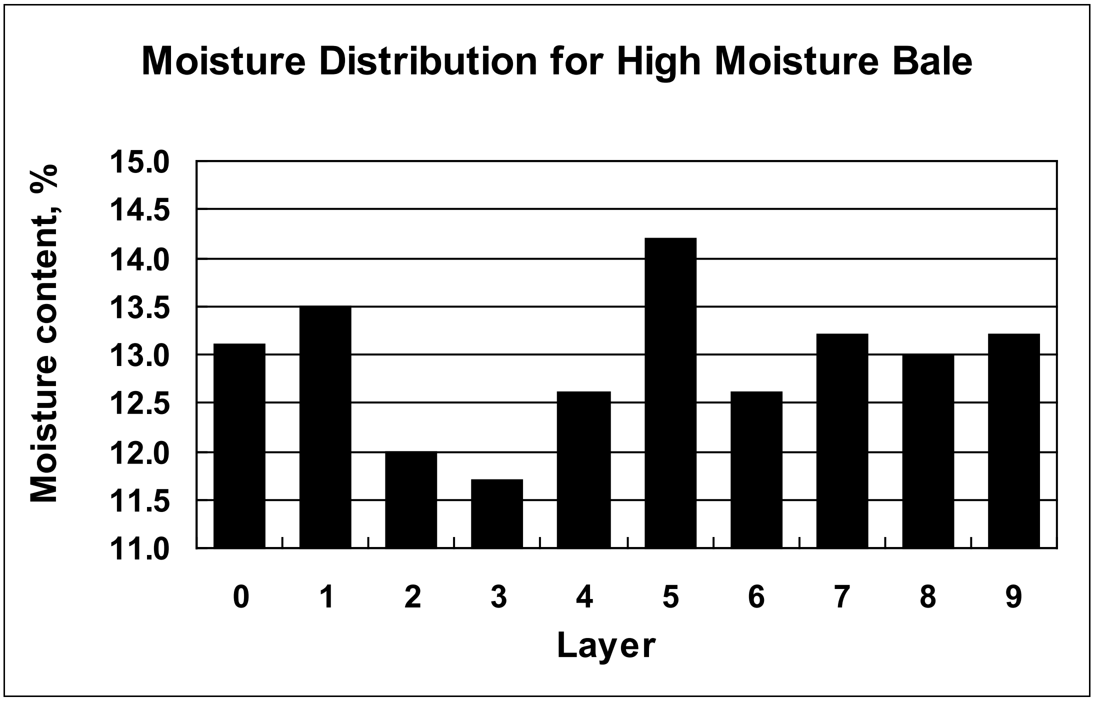


Figure 9. Average moisture at each of the 10 locations within the bale beginning about 7.62 cm (3-inches) from the exterior for Study 1.

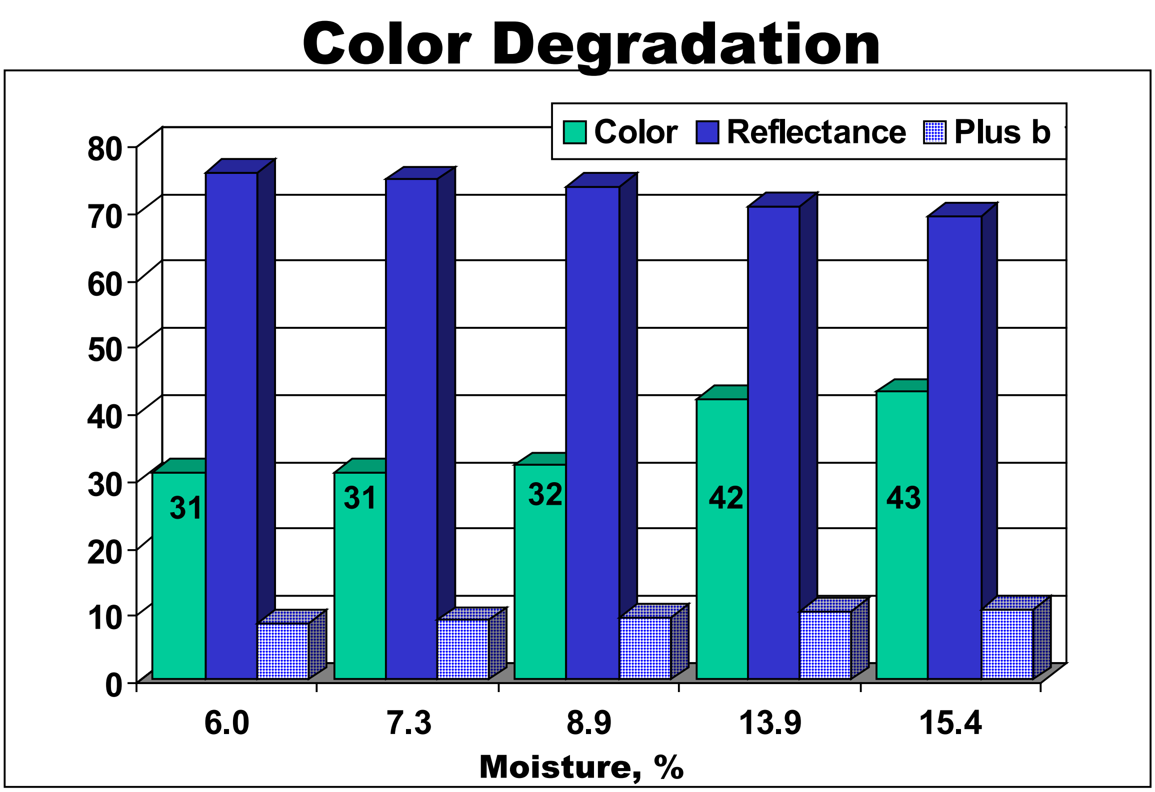


Figure 10. Impact of moisture on cotton color during bale storage for 116 days for Study 1.

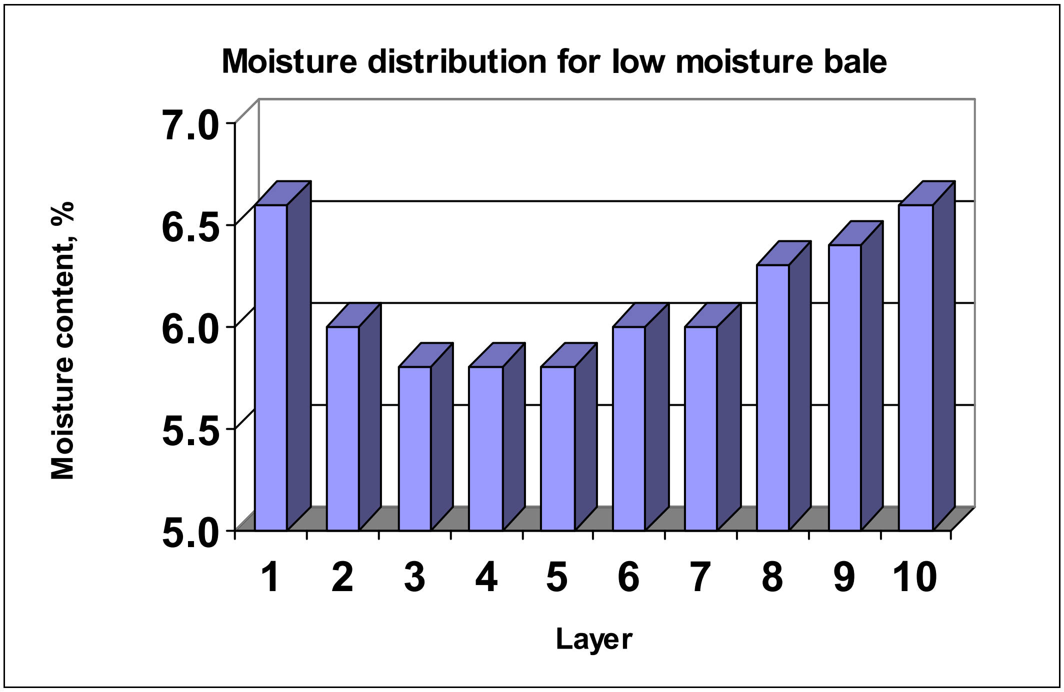


Figure 11. Average moisture at each of the 10 locations within the bale beginning about 7.62 cm (3-inches) from the exterior. Initial bale moisture was 4.8% and final moisture **after** storage was 6.1%. Bales were stored in strip-coated, woven polypropylene bags.

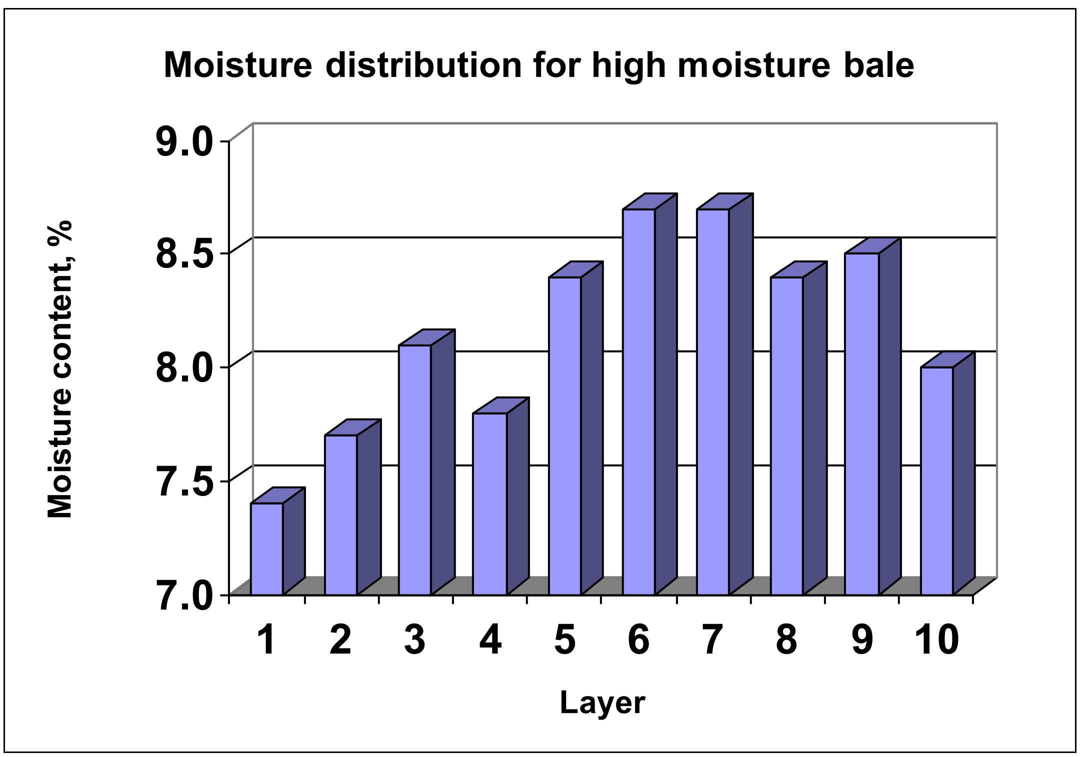


Figure 12. Average moisture at each of the 10 locations within the bale beginning about 7.62 cm (3-inches) from the exterior for Study 2. Initial moisture was 12.7% and final bale moisture **after** storage was 8.2%. Bales were stored in strip-coated, woven polypropylene bags.

Figure 13. Discoloration occurred near the bale tie for the bales where moisture was added for Study 2.

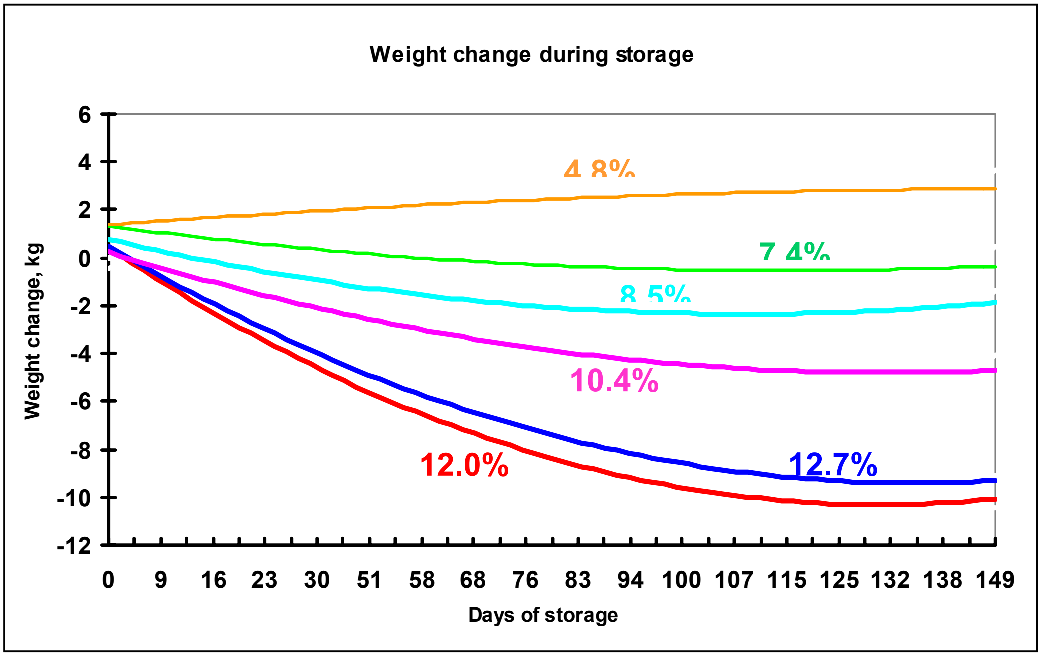


Figure 14. Weight change, kg per bale, during storage for Study 2. Note that all bales did not weigh the same initially. Moistures shown are initial, not final.

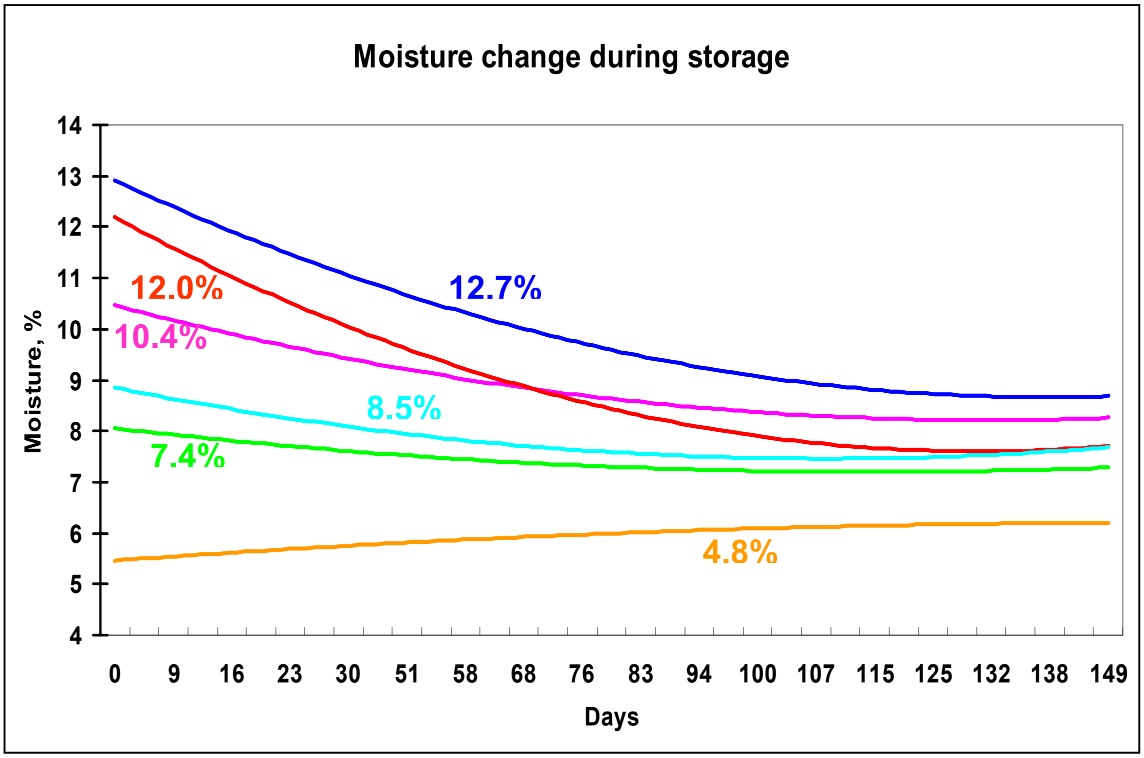


Figure. 15. Change in bale moisture content during storage in woven polypropylene, strip-coated bags for Study 2. Moistures were calculated based on weight change of each bale.

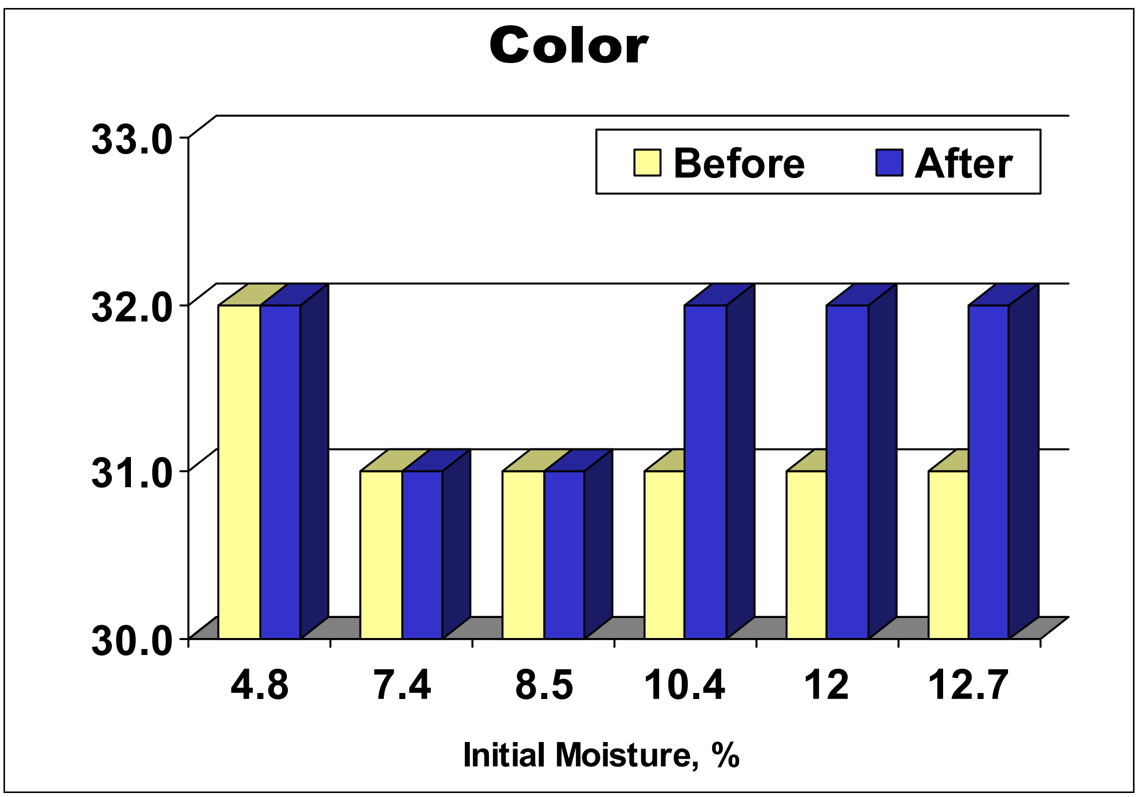


Figure 16. Impact of moisture on cotton color before and after bale storage (based on average Rd and +b) for Study 2.

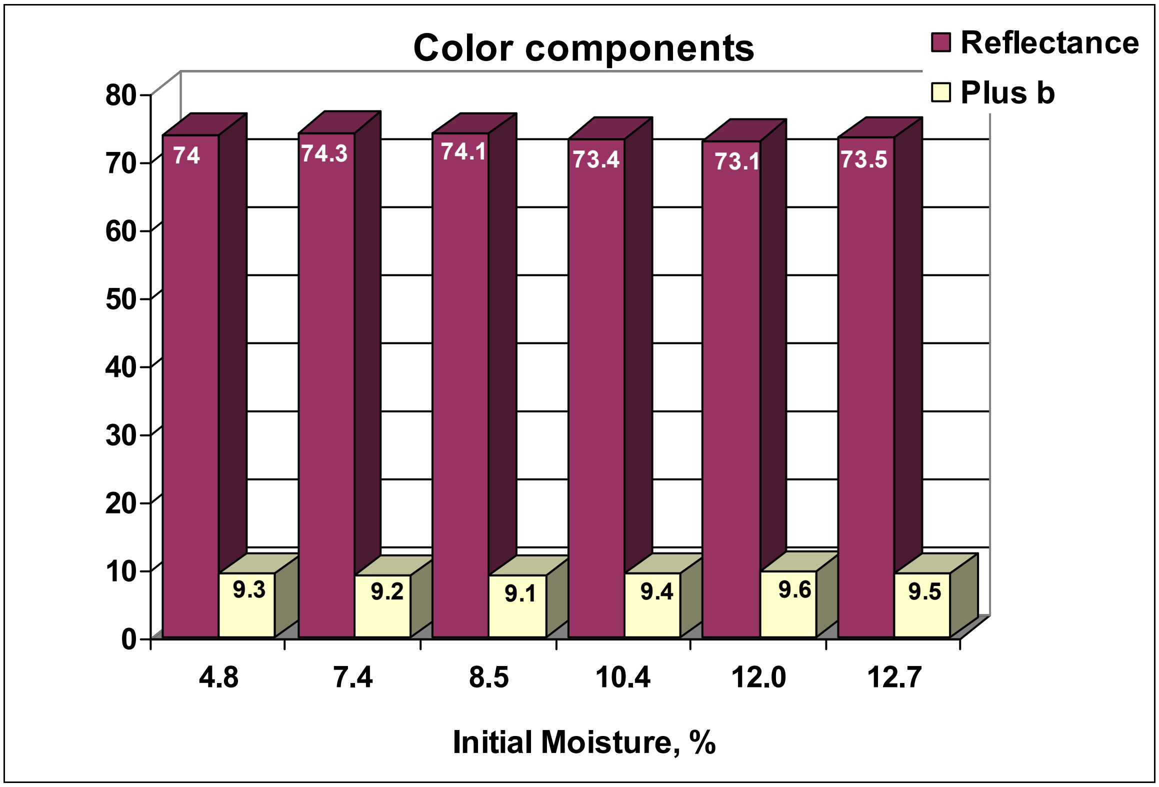


Figure 17. Cotton color factors before bale storage for 149 days at moisture levels of 4.8 to 12.7% for Study 2. Bales were stored in strip-coated, woven polypropylene.

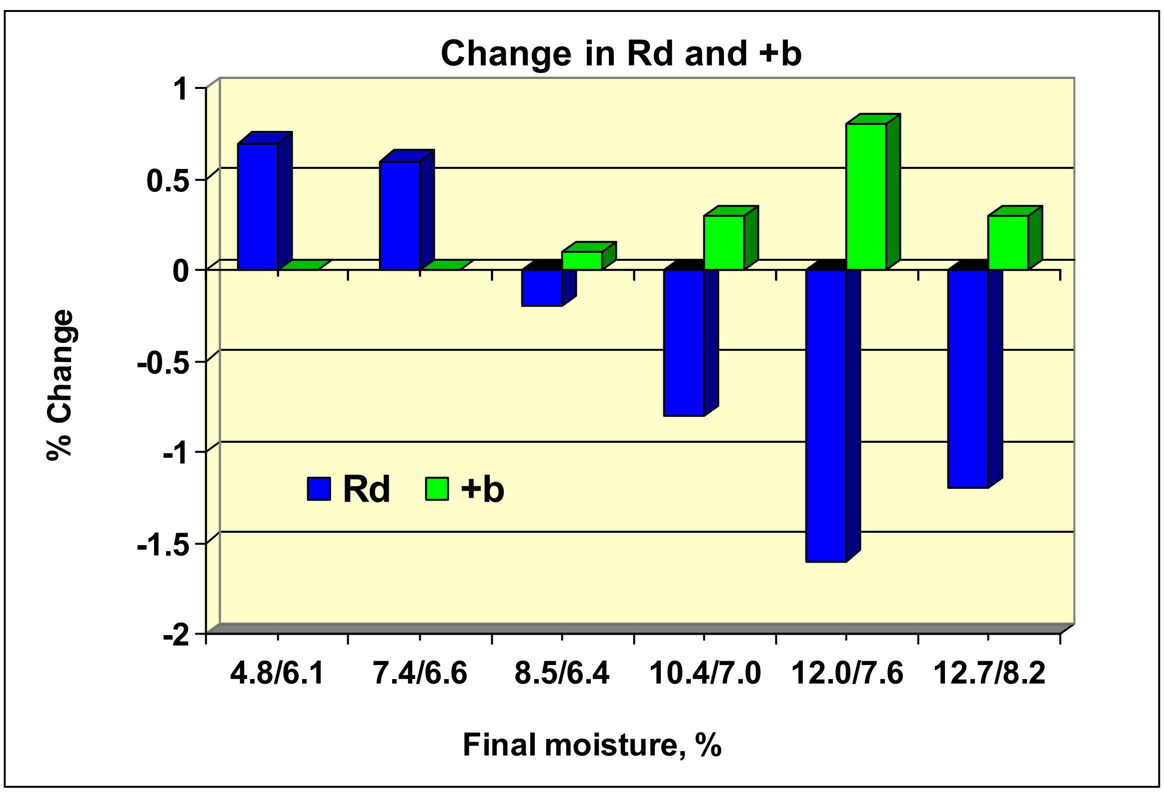


Figure 18. Change in reflectance (Rd) and yellowness (+b) during storage for Study 2.

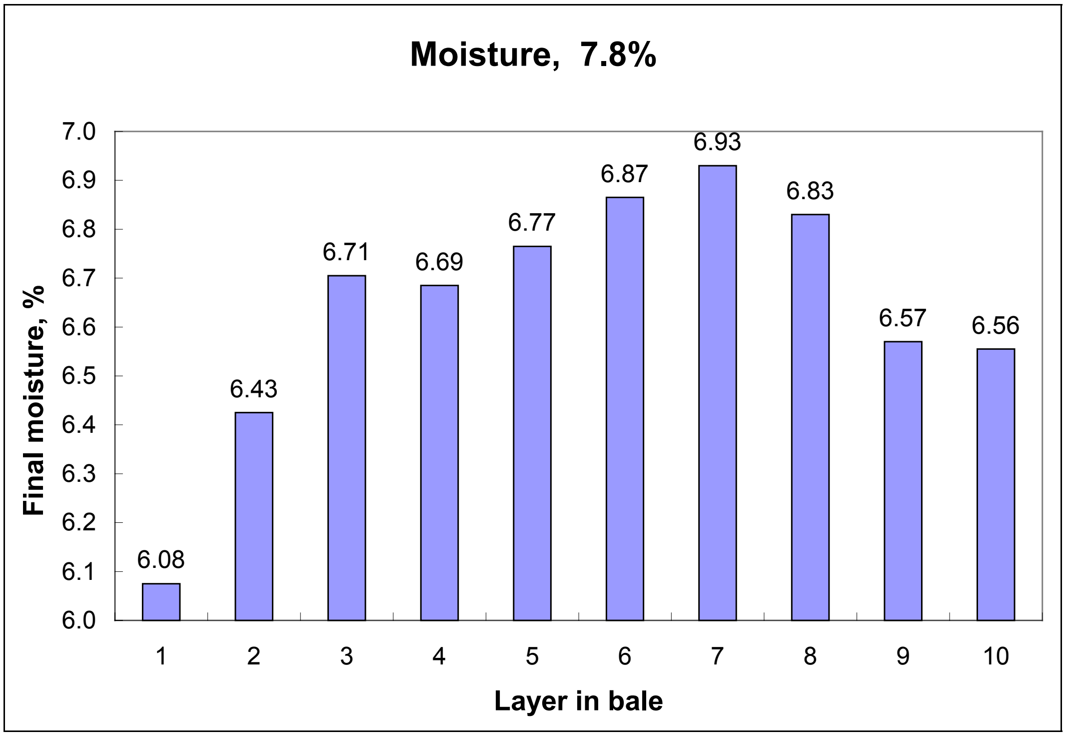


Figure 19. Average moisture at each of the 10 locations within the low moisture bale beginning about 7.62 cm (3-inches) from the exterior for Study 3. Initial moisture was 7.8% and final bale moisture after storage was 6.6%. Bale 1047 (control) was stored in a strip-coated, woven polypropylene bag.

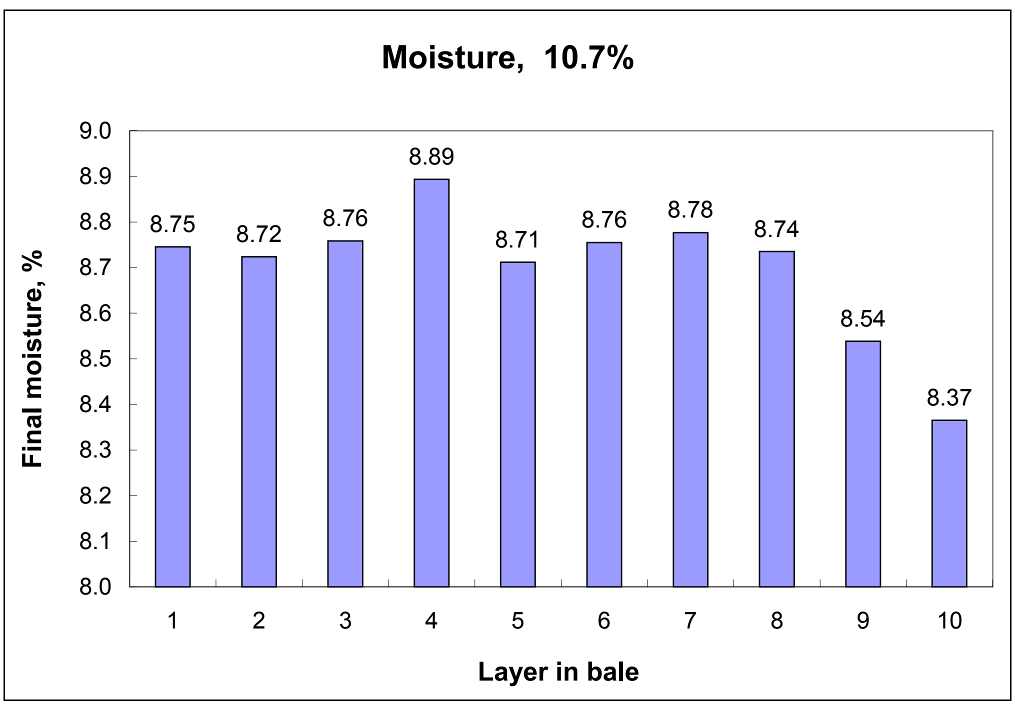


Figure 20. Average moisture at each of the 10 locations within the high moisture bale beginning about 7.62 cm (3-inches) from the exterior for Study 3. Initial moisture was 10.7% and final bale moisture **after** storage was 8.7%. Bales were stored in fully coated, woven polypropylene bags.

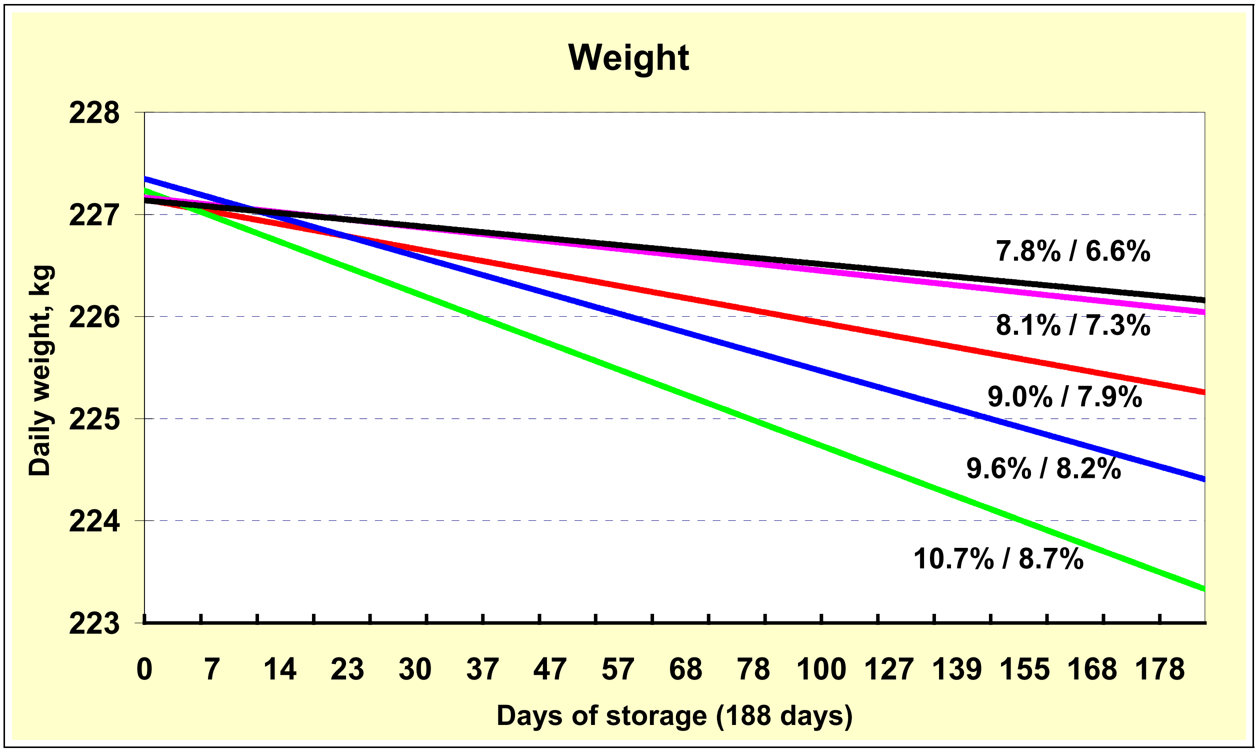


Figure 21. Weight change of bales during storage for Study 3. Note that all bales did not weigh the same initially, but these data are adjusted to 227 kg (500 lb).

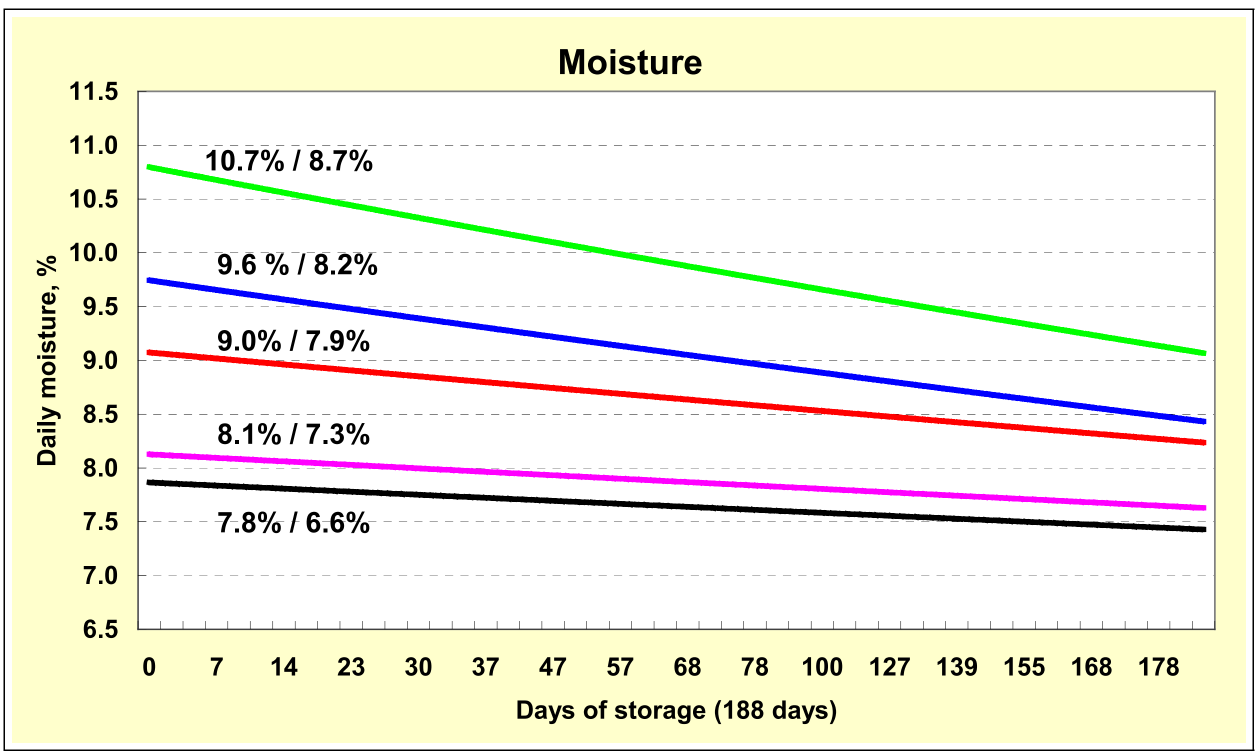


Figure. 22. Change in moisture content during storage in fully coated woven polypropylene bags for Study 3, and the bale stored in a strip-coated woven polypropylene bag.

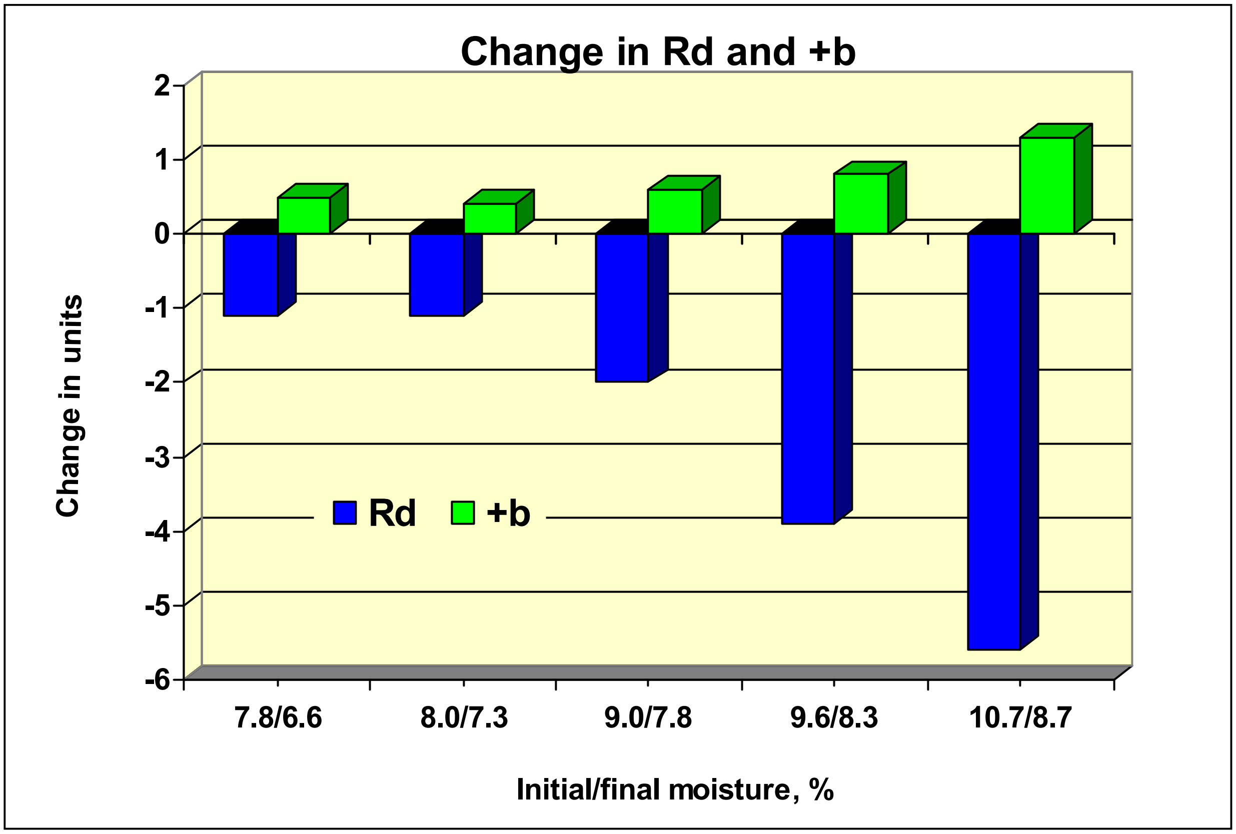


Figure 23. Changes in Rd and Plus b during 188 days storage of bales in fully-coated, woven polypropylenebags, except for the 7.8% bale that was stored in strip-coated woven polypropylene for Study 3.

## Appendix or Nomenclature

| | |
|---|---|
| NEP SIZE [µM] | The mean size of all neps (both fiber and seed coat neps) in the sample. |
| NEPS PER GRAM | The total nep count normalized per gram. This includes both fiber and seed coat neps. |
| L(W) [CM] | The average length of all the fibers in the sample computed on a weight basis. |
| L(W) CV [%] | The percentage of the coefficient of variation of the length by weight. |
| UQL(W) [CM] | Upper quartile length by weight. This is the length which is exceeded by 25% of the fibers by weight. |
| SFC(W) [%] | The short fiber content of the sample (calculated by weight). |
| L(N) [CM] | The average length of all the fibers in the sample computed on a number basis. |
| L(N) CV [%] | The percentage of the coefficient of variation of the length by number. |
| SFC(N) [%] | The short fiber content of the sample (actual fibers counted by number). |
| L5%(N) [CM] | The length, calculated by number, that is exceeded by five percent of the fibers. |
| L2.5%(N) [CM] | The length, calculated by number, that is exceeded by 2.5 percent of the fibers. |
| TOTAL TRASH [count/gram] | Total trash consists of trash and dust; this is the total of the trash and dust count per gram of the sample. |
| TRASH SIZE [µM] | The mean size of all the trash in the sample. |
| DUST [COUNT/GRAM] | The particles measured by the trash module that are below the size defined as dust on the trash report type setup screen. |
| TRASH [COUNT/GRAM] | All foreign matter in cotton that is above the size defined as dust is considered trash. This is the amount of trash per gram of the sample. |
| VFM [%] | The percentage of visible foreign matter (dust and trash) in the sample. |
| SCN SIZE [µM] | The mean size of all seed coat neps in the sample. |
| SCN PER GRAM | The seed coat nep count normalized per gram. |
| FINE [MTEX] | Fineness - mean fiber fineness (weight per unit length) in millitex. One Thousand meters of fibers with a mass of 1 milligram equals 1 millitex. |
| IFC [%] | immature fiber content is the percentage of fibers with less than 0.25 maturity. The lower the ifc%, the more suitable the fiber is for dyeing. |
| MAT RATIO | Maturity ratio - the ratio of fibers with a 0.5 (or more) circularity ratio divided by the amount of fibers with a 0.25 (or less) circularity. The higher the maturity ratio, the more mature the fibers are and the better the fibers are for dyeing. |
| MICRONAIRE | Micronaire is a measure of fiber fineness and maturity. |
| STRENGTH | Strength measurements are reported in terms of grams per tex. A tex unit is equal to the weight in grams of 1,000 meters of fiber. |
| RD AND PLUSB | The color of cotton is determined by the degree of reflectance (rd) and yellowness (+b). Reflectance indicates how bright or dull a sample is, and yellowness indicates the degree of color pigmentation. |
| PERCENT AREA | Trash is a measure of the amount of non-lint materials in the cotton, such as leaf and bark from the cotton plant. The surface of the cotton sample is scanned by a video camera and the percentage of the surface area occupied by trash particles is calculated. |
| LENGTH | Fiber length is the average length of the longer one-half of the fibers (upper half mean length). |
| UNIFORM | Length uniformity is the ratio between the mean length and the upper half mean length of the fibers and is expressed as a percentage. |